



NIST
National Institute of
Standards and Technology

**FY 2012
Small Business Innovation Research
Program**

SOLICITATION

U.S. DEPARTMENT OF COMMERCE

National Institute of Standards and Technology

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PROGRAM SOLICITATION AVAILABLE IN ELECTRONIC FORM ONLY

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**US DEPARTMENT OF COMMERCE NATIONAL INSTITUTE OF STANDARDS
AND TECHNOLOGY**

**SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM
SOLICITATION**

1.0 PROGRAM DESCRIPTION

1.01 Introduction

The National Institute of Standards and Technology (NIST) invites small businesses to submit research proposals under this solicitation. Firms with strong research capabilities in any of the areas listed in Section 9 of this solicitation are encouraged to participate. **Unsolicited proposals are not accepted under the SBIR program.**

The objectives of the SBIR program are to: stimulate technological innovation in the private sector; strengthen the role of small business in meeting Federal research and development (R&D) needs; foster and encourage participation by socially and economically disadvantaged persons and women-owned small business concerns in technological innovation; and increase private sector commercialization of innovations derived from federal research and development. The NIST SBIR Program identifies and solicits proposals in subtopics that fall within NIST's mission and allow collaboration between NIST scientists and the SBIR awardees whenever possible. In order to ensure a greater strategic alignment between the NIST SBIR program and our laboratory research program, the SBIR topics are the investment priorities areas identified in the NIST Programmatic Plan available at: <http://www.nist.gov/director/planning/planning.cfm>.

The SBIR program was originally established in 1982 by the Small Business Innovation Development Act (P.L. 97-219). It was then expanded by the Small Business R&D Enhancement Act of 1992, extending the program to the year 2000 and then to 2008. Currently the SBIR program has not been reauthorized but Congress has extended the program under a continuing resolution through December 16, 2011. Note: The evaluation of proposals, source selection, and award of contracts under the solicitation is contingent upon the continued existence of the SBIR program. Eleven federal agencies set aside a portion of their extramural research and development budget each year to fund research proposals from small science and technology-based firms.

Subtopics

NIST offers two types of Subtopics in Section 9 of this solicitation: standard research "R" and tech transfer "TT" Subtopics.

1.01.01 NIST SBIR “R” Subtopics

Subtopics with the “R” designation address the objective of stimulating small business innovation in areas that meet NIST’s programmatic goals. The “R” subtopics are designed to give small, high tech companies opportunities to propose cutting-edge innovations that meet NIST’s technological needs and at the same time have market potential beyond NIST.

1.01.02 NIST SBIR”TT” Subtopics

Subtopics with the “TT” designation address the objective of increasing the commercial application of innovations derived from Federal R&D. SBIR-TT subtopics identify a commercially promising NIST derived technology and the technological gaps needed to transition it to the marketplace. While NIST Laboratory scientists conduct breakthrough research that leads to innovations, NIST’s efforts do not extend to product development. The remaining work needed to develop NIST technologies for the marketplace requires innovation from the private sector.

Both “R” and “TT” subtopics are intended to cultivate private sector innovation and foster and encourage participation by minority and disadvantaged persons in technological innovation.

Technologies identified with “TT” subtopics are either dedicated to the public domain or are patent protected. If there is no patent or patent application cited, the technology is freely available for use without the need for any license. If a “TT” subtopic cites a patent or patent application, the use of that background invention during the course of the SBIR project requires a patent license. All offerors submitting proposals addressing a subtopic that cites background patented technology must submit a non-exclusive, royalty-free license application which is available at the [NIST SBIR website](#). Only those non-exclusive, royalty-free research license applications accompanying proposals that result in an SBIR award under this solicitation will be granted.

SBIR awards resulting from “TT” subtopics will include, as necessary, the grant of a non-exclusive research license to use the NIST-owned patented background inventions specifically identified within the “TT” subtopic being awarded. SBIR offerors are hereby notified that no exclusive or non-exclusive commercialization license to make, use or sell products or services incorporating the NIST background invention will be granted until an SBIR awardee applies for, negotiates and receives such a license. Awardees with contracts for subtopics that identify specific NIST-owned patented background inventions will be given the opportunity to negotiate a non-exclusive commercialization license to such background inventions. If available, Awardees may be given the opportunity to negotiate an exclusive commercialization license to such background inventions. License applications will be treated in accordance with Federal patent licensing regulations as provided in 37 CFR Part 404.

Once awarded a contract and, where necessary, granted a license to use NIST

technology and access to NIST personnel knowledgeable about the invention, it is the goal of this program that the SBIR awardee will be positioned to create and add its own innovation and potentially develop a commercially viable product based on the NIST patent.

1.02 Three-Phase Program

The "Small Business Research and Development Enhancement Act of 1992", as amended, requires the Department of Commerce to establish a three-phase SBIR program by reserving a percentage of its extramural R&D budget to be awarded to small business concerns for innovation research. SBIR Policy is provided by the Small Business Administration through the SBA Policy Directive.

The funding vehicles for NIST's SBIR program in both Phase 1 and Phase 2 are contracts. **This solicitation is for Phase 1 proposals only.** A Phase 2 proposal can be submitted only by a Phase 1 awardee and only in response to a NIST request to participate upon successful completion of Phase 1.

NIST has the unilateral right to select SBIR research topics and awardees in both Phase 1 and Phase 2 and award several or no contracts under a given subtopic.

1.02.01 Phase 1 - Feasibility Research

The purpose of Phase 1 is for NIST to determine the technical feasibility of the research the awardee proposes and the quality of the awardee's performance. Therefore, the proposal should concentrate on describing research that will significantly contribute to proving the feasibility of the proposed research, a prerequisite to further support in Phase 2. NIST Phase 1 awards are up to \$90,000 and up to a 7 month period of performance.

1.02.02 Phase 2 - Research and Development

Only firms that are awarded Phase 1 contracts under this solicitation will be given the opportunity to submit a Phase 2 proposal following completion of Phase 1. Instructions for Phase 2 proposal preparation and submission will be provided to Phase 1 awardees typically toward the end of the Phase 1 period of performance. Phase 2 applicants will be required to provide information for the SBA Tech-Net Database System (<http://tech-net.sba.gov>) when advised this system can accept their input.

Phase 2 is the R&D or prototype development phase. It will require a comprehensive proposal outlining the research. Further information regarding Phase 2 proposal requirements will be provided to all firms receiving Phase 1 awards. NIST Phase 2 awards are up to \$300,000 and up to a 24 month period of performance.

1.02.03 Phase 3 - Commercialization

In Phase 3, it is intended that non-SBIR capital be used by the small business to pursue commercial applications of Phase 2. SBIR funds are not available for Phase 3.

1.03 Manufacturing-related Priority

[Executive Order \(EO\) 13329](#) “Encouraging Innovation in Manufacturing” requires SBIR agencies, to the extent permitted by law and in a manner consistent with the mission of that department or agency, to give high priority within the SBIR programs to manufacturing-related research and development (R&D). “Manufacturing-related” is defined as “relating to manufacturing processes, equipment and systems; or manufacturing workforce skills and protection.” More information on the national manufacturing initiative may be found through links located on the [NIST SBIR website](#).

The NIST SBIR Program solicits manufacturing-related projects through many of the subtopics described in this Solicitation. Further, NIST encourages innovation in manufacturing by giving high priority, where feasible, to projects that can help the manufacturing sector through technological innovation in a manner consistent with NIST’s mission. This prioritization will not interfere with the core project selection criteria: scientific and technical merit, and the potential for commercial success.

1.04 Energy Efficiency and Renewable Energy Priority

The Energy Independence and Security Act of 2007 (P.L. 110-140) directs SBIR Programs to give high priority to small business concerns that participate in or conduct energy efficiency or renewable energy system R&D projects.

The NIST SBIR Program solicits energy efficiency or renewable energy system R&D projects through some of the subtopics described in this Solicitation. Further, NIST encourages innovation in energy efficiency or renewable energy system R&D by giving high priority, where feasible, to projects that conduct energy efficiency or renewable energy system R&D through technological innovation in a manner consistent with NIST’s mission. This prioritization will not interfere with the core project selection criteria: scientific and technical merit, and the potential for commercial success.

1.05 SBIR Proposer Eligibility and Limitations

Each proposer for both Phase 1 and Phase 2 must qualify as a small business concern ([Section 2.12](#)) for research or R&D purposes ([Section 2.9](#)) at the time of award. In addition, the primary employment of the principal investigator must be with the small business at the time of the award and during the conduct of the proposed research. Primary employment means that more than one-half of the principal investigator's time is spent with the small business. **Primary employment with a small business precludes full-time employment with another organization.**

For both Phase 1 and Phase 2, all work must be performed by the small business concern and its subcontractors in the United States. "United States" means the fifty states, the territories and possessions of the United States, the Commonwealth of Puerto Rico, the Commonwealth of the Northern Mariana Islands, the Trust Territory of the Pacific Islands, and the District of Columbia. However, based on a rare and unique circumstance, for example, a supply or material or other item or project requirement that is not available in the United States, NIST may allow that particular portion of the Research or R&D work to be performed or obtained in a country outside of the United States. Approval by the funding agreement officer after consultation with NIST SBIR Program Manager/Coordinator for each such specific condition must be in writing.

Joint ventures and limited partnerships are eligible, provided the entity created qualifies as a small business as defined in this solicitation. The small business awardee may enter into subcontracts with universities or other non-profit organizations, with the awardee serving as the prime contractor.

For Phase 1, a minimum of two-thirds of the research and/or analytical effort must be performed by the awardee. For Phase 2, a minimum of one-half of the research and/or analytical effort must be performed by the awardee.

Unsolicited proposals or proposals not responding to subtopics listed herein are not eligible for SBIR awards. Only proposals that are directly responsive to the subtopics as described in Section 9 will be considered.

Potential awardees may not participate in the selection of any topic or subtopic nor in the review of proposals. All offerors, including Guest Researchers, contractors, Cooperative Research and Development Agreement (CRADA) partners and others working with NIST may only submit a proposal if they:

- Had no role in suggesting, developing, or reviewing the subtopic
- Have not been the recipient of any information on the subtopic not available in the solicitation or other public means
- Have not received any assistance from DOC in preparing the proposal (including any 'informal' reviews) prior to submission.

NIST may not enter into, or continue an existing CRADA with an awardee on the subtopic of the award.

1.06 Contact with NIST

In the interest of competitive fairness, all oral or written communication with NIST concerning a specific technical topic or subtopic during the open solicitation period is strictly prohibited - with the exception of the public discussion group located at <http://www.nist.gov/sbir>. Discussion group questions will be routed to the appropriate person for a response. All questions and responses will be publicly, though anonymously, posted on the discussion group web site.

For general information on the NIST SBIR program contact:

SBIR Program
100 Bureau Drive, Stop 2200
Gaithersburg, MD 20899-2200

Telephone: (301) 975-4188, Fax: (301) 975-3482
Email: sbir@nist.gov

For information on contractual issues contact:

Micole Cheatham
Acquisitions and Management Division

Telephone: (301) 975-8335
Email: mcheath@nist.gov

2.0 DEFINITIONS

2.01 Commercialization

The process of developing marketable products or services and producing and delivering products or services for sale (whether by the originating party or by others) to the Government or commercial markets.

2.02 Essentially Equivalent Work

This occurs when (1) substantially the same research is proposed for funding in more than one contract proposal or grant application submitted to the same Federal agency; (2) substantially the same research is submitted to two or more different Federal agencies for review and funding consideration; or (3) a specific research objective and the research design for accomplishing an objective are the same or closely related in two or more proposals or awards, regardless of the funding source.

2.03 Feasibility

The practical extent to which a project can be performed successfully.

2.04 Funding Agreement

Any contract, grant, or cooperative agreement entered into between any Federal agency and any small business concern (SBC) for the performance of experimental, developmental, or research work, including products or services, funded in whole or in part by the Federal Government. For purposes of this Solicitation, NIST intends to award purchase orders and/or contracts in accordance with the Federal Acquisition Regulation.

2.05 Historically Underutilized Business Zone (HUBZone) Small Business Concern

Status as a qualified HUBZone Small Business Concern is determined by the Small Business Administration in accordance with 13 CFR Part 126.

2.06 Joint Venture

An association of persons or concerns with interests in any degree or proportion by way of contract, express or implied, consorting to engage in and carry out a single specific business venture for joint profit, for which purpose they combine their efforts, property, money, skill, or knowledge, but not on a continuing or permanent basis for conducting business generally. A joint venture is viewed as a business entity in determining power to control its management and is eligible under the SBIR and STTR Programs provided that the entity created qualifies as a "small business concern" as defined in herein.

2.07 NIST-Owned Patented Background Inventions

There is a background NIST technology, for each "TT" subtopic contained in this Solicitation, some of which are patent protected. NIST-Owned Patented Background Inventions are those patented technologies that NIST owns and has retained patent rights.

2.08 Primary Employment

Primary employment means that more than one half of the principal investigator's time is spent in the employ of the small business concern. This requirement extends also to "leased" employees (workers who are employed by a third-party leasing company) serving as the principal investigator. Primary employment with a small business concern precludes full time employment at another organization.

2.09 Research or Research and Development

Any activity that is (a) a systematic, intensive study directed toward greater knowledge or understanding of the subject studied; (b) a systematic study directed specifically toward applying new knowledge to meet a recognized need; or (c) a systematic application of knowledge toward the production of useful materials, devices, services, or methods, and includes design, development, and improvement of prototypes and new processes to meet specific requirements.

2.10 SBIR Technical Data

All data generated during the performance of an SBIR award.

2.11 SBIR Technical Data Rights

The rights an SBC obtains in data generated during the performance of any SBIR Phase 1, Phase 2, or Phase 3 award that an awardee delivers to the Government during or upon completion of a Federally-funded project, and to which the Government receives a license.

2.12 Small Business Concern (SBC)

A Small Business Concern is one that, on the date of award for both Phase 1 and Phase 2 funding agreements, meets all of the following criteria:

- (1) is organized for profit, with a place of business located in the United States, which operates primarily within the United States or which makes a significant contribution to the United States economy through payment of taxes or use of American products, materials or labor;
- (2) is in the legal form of an individual proprietorship, partnership, limited liability company, corporation, joint venture, association, trust or cooperative, except that where the form is a joint venture, there can be no more than 49 percent participation by business entities in the joint venture;
- (3) is (i) at least 51 percent owned and controlled by one or more individuals who are citizens of the United States or permanent resident aliens in the United States, (ii) at least 51% owned and controlled by another business concern that is itself at least 51% owned and controlled by individuals who are citizens of, or permanent resident aliens in the United States; or (iii) a joint venture in which each entity to the venture must meet the requirements of either (i) or (ii) of this section.
- (4) has, including its affiliates, not more than 500 employees.

Control can be exercised through common ownership, common management, and contractual relationships. The term "affiliates" is defined in greater detail in [13 CFR 121.103](#). The term "number of employees" is defined in [13 CFR 121.106](#) as "all individuals employed on a full-time, part-time, or other basis."

A business concern may be in the form of an individual proprietorship, partnership, limited liability company, corporation, joint venture, association, trust, or cooperative. Further information may be obtained at <http://www.sba.gov/size>, or by contacting the Small Business Administration's Government Contracting Area Office or Office of Size Standards.

2.13 Socially and Economically Disadvantaged Small Business Concern

A socially and economically disadvantaged small business concern is one that is at least 51% owned and controlled by one or more socially and economically disadvantaged individuals, or an Indian tribe, including Alaska Native Corporations (ANCs), a Native Hawaiian Organization (NHO), or a Community Development

Corporation (CDC). Control includes both the strategic planning (as that exercised by boards of directors) and the day-to-day management and administration of business operations. See 13 CFR 124.109, 124.110, and 124.111 for special rules pertaining to concerns owned by Indian tribes (including ANCs), NHOs or CDCs, respectively.

2.14 Subcontract

Any agreement, other than one involving an employer-employee relationship, entered by the awardee of a Federal Government funding agreement, calling for supplies or services required solely for the performance of the original funding agreement.

2.15 Women-Owned Small Business

As defined by Federal Acquisition Regulations (FAR) Part 19.001, “Women-owned small business concern means a small business concern — (a) which is at least 51 percent owned by one or more women; or, in the case of any publicly owned business, at least 51 percent of the stock of which is owned by one or more women; and (b) whose management and daily business operations are controlled by one or more women.”

3.0 PROPOSAL PREPARATION INSTRUCTIONS AND REQUIREMENTS

3.01 Proposal Requirements

NIST reserves the right to not submit to technical review any proposal which it determines has insufficient scientific and technical information, or one which fails to comply with the administrative procedures as outlined on the Checklist of Requirements in [Section 8.05](#). Proposals that do not successfully pass the screening criteria given in [Section 4.02](#) will be returned to the offeror without further consideration.

The offeror must provide sufficient information to demonstrate that the proposed work represents a sound approach to the investigation of an important scientific or engineering innovation worthy of support. The proposal must meet all the requirements of the subtopic in Section 9 it addresses.

A proposal must be self-contained and written with all the care and thoroughness of a scientific paper submitted for publication. It should indicate a thorough knowledge of the current status of research in the subtopic area addressed by the proposal. Each proposal should be checked carefully by the offeror to ensure inclusion of all essential material needed for a complete evaluation. The proposal will be peer reviewed as a scientific paper. All units of measurement should be in the metric system.

The proposal must not only be responsive to the specific NIST program interests described in Section 9 of the solicitation, but also serve as the basis for technological innovation leading to new commercial products, processes, or services that benefit the public. An offeror may submit proposals on multiple subtopics or multiple proposals on

one subtopic under this solicitation. When the proposed innovation applies to more than one subtopic, the offeror must submit its proposal under the subtopic that is most relevant to the offeror's technical concept.

Proposals principally for the commercialization of proven concepts or for market research must not be submitted. Such efforts are considered the responsibility of the private sector.

The proposal should be direct, concise, and informative. Promotional and other material not related to the project shall be omitted.

3.02 Phase 1 Proposal Limitations

- Page length - **no more than 25 pages**, consecutively numbered, including the cover sheet (2 pages count as one – for the cover sheet only), project summary, main text, references, resumes, other enclosures or attachments, and the proposal summary budget. The only exception to the page count limitation is the Company Commercialization History Template, as required per [Section 3.03.03.02](#).
- Paper size - must be 21.6 cm X 27.9 cm (8 ½" X 11").
- Print size - must be easy to read with a fixed pitch font of 12 or fewer characters per inch or proportionally spaced font of point size 10 or larger with no more than 6 lines per inch.

Supplementary material, revisions, substitutions, audio or video tapes, or computer storage media or devices will **not** be accepted.

Proposals not meeting these requirements will be returned without review.

3.03 Phase 1 Proposal Submission Forms and Technical Content

This section provides instructions for completing required forms and writing the Technical Content section. A complete proposal application must include **four copies** of each of the following:

- (a) Cover Sheet (required form, see [Section 8.01](#))
- (b) Project Summary (required form, see [Section 8.02](#))
- (c) Technical Content (up to 22 pages)
- (d) Commercialization History Template, (see [Section 8.03](#)), required only for firms that have received one or more SBIR/STTR awards from any federal agency).

(e) Proposed Budget (required form, see [Section 8.04](#))

Proposals received missing any of these required items will be returned without review.

For Instructions for Proposal Submission, see [Section 6.0](#).

3.03.01 [Cover Sheet](#)

Complete the "Cover Sheet" (Section 8.1) as page 1 of the proposal. Please ensure that required signatures on page 1b are included. **No other Cover Sheet will be accepted.**

If you check the box on page 2 of the Cover Sheet, your contact information will be provided to NIST Hollings Manufacturing Extension Partnership (MEP). They will forward your information to regional economic development organizations in your state which offer an array of resources and services dedicated to helping you succeed.

Before NIST can award a contract to a successful offeror under this solicitation, the offeror must be registered in the DoD Central Contractor Registration (CCR) database. The CCR allows Federal Government contractors or firms interested in conducting business with the federal government to provide basic information on business capabilities and financial information. To register, visit <http://www.ccr.gov> or call 1-866-606-8220.

The DUNS number is a nine-digit number assigned by Dun and Bradstreet Information Services. If the offeror does not have a DUNS number, it should contact Dun and Bradstreet directly to obtain one. A DUNS number will be provided immediately by telephone at no charge to the offeror. For information on obtaining a DUNS number, the offeror, if located within the United States, should call Dun and Bradstreet at 1-800-333-0505, or access their website at <http://sbs.dnb.com>.

No award shall be made under this solicitation to a small business concern without registration in CCR and a DUNS number.

Be sure to identify proposal page numbers that contain confidential information in the Proprietary Notice section at the end of the Cover Sheet.

3.03.02 [Project Summary](#)

Complete the "Project Summary" form (Section 8.02) as page 2 of your proposal. The technical abstract should include a brief description of the problem or opportunity, the innovation, project objectives, and technical approach. In summarizing anticipated results, include technical implications of the approach and the potential commercial

applications of the research. **Each awardee's Project Summary will be published by NIST on the [NIST SBIR website](#) and www.sbir.gov and, therefore, must not contain proprietary information.**

3.03.03 Technical Content

Beginning on page 3 of the proposal, include the following items with headings as shown:

(a) **Identification and Significance of the Problem or Opportunity.** Make a clear statement of the specific research problem or opportunity addressed, its innovativeness, commercial potential, and why it is important. Show how it applies to a specific subtopic in Section 9.

(b) **Phase 1 Technical Objectives.** State the specific objectives of the Phase 1 effort, including the technical questions it will try to answer, to determine the feasibility of the proposed approach.

(c) **Phase 1 Work Plan.** Include a detailed description of the Phase 1 feasibility research plan. The plan should indicate what will be done, where it will be done, and how the research will be carried out. The method(s) planned to achieve each objective or task, mentioned in item (b) above, should be discussed in detail. **This section should be at least one-third of the proposal.**

NIST technical support or assistance will be available to awardees in the conduct of the research only if specifically provided for in the subtopic description.

(d) **Related Research or R&D.** Describe research or R&D that is directly related to the proposal, including any conducted by the principal investigator or by the proposer's firm. Describe how it relates to the proposed effort, and describe any planned coordination with outside sources. The purpose of this section is to demonstrate the offeror's awareness of recent developments in the specific topic area.

(e) **Key Personnel and Bibliography of Related Work.** Identify key personnel involved in Phase 1, including their related education, experience, and publications. Where resumes are extensive, summaries that focus on the most relevant experience and publications are suggested. List all other commitments that key personnel have during the proposed period of contract performance.

(f) **Relationship with Future R&D.** Discuss the significance of the Phase 1 effort in providing a foundation for the Phase 2 R&D effort. Also state the anticipated results of the proposed approach, if Phases 1 and 2 of the project are successful.

(g) **Facilities and Equipment.** The conduct of advanced research may require the

use of sophisticated instrumentation or computer facilities. The offeror should provide a detailed description of the availability and location of the facilities and equipment necessary to carry out Phase 1. **NIST facilities and/or equipment will be available for use by awardees only if specifically provided for in the subtopic description.** All related transportation/shipping/insurance costs shall be the sole responsibility of the contractor. If expressed in the subtopic description that access to NIST resources will be made available, then under mutual agreement between awardee and NIST staff, arrangements will be planned prior to NIST labs visits, samples testing or exchange, and any collaborative discussions.

(h) **Consultants and Subcontracts.** The purpose of this section is to show that: research assistance from outside the firm materially benefits the proposed effort, and arrangements for such assistance are in place at time of proposal submission.

Outside involvement in the project is encouraged where it strengthens the conduct of the research. Outside involvement is not a requirement of this solicitation. **Outside involvement is limited to no more than 1/3 of the research and/or analytical effort in Phase 1, per [Section 1.05](#).**

1. Consultant - A person outside the firm, named in the proposal as contributing to the research, must provide a signed statement confirming his/her availability, role in the project, and agreed consulting rate for participation in the project. **This statement is part of the page count.**

2. Subcontract - Similarly, where a subcontract is involved in the research, the subcontracting institution must furnish a letter signed by an appropriate official describing the programmatic arrangements and confirming its agreed participation in the research, with its proposed budget for this participation. **This letter is part of the page count.**

Absence of such documents explaining such a consultant or subcontract, if cited elsewhere in the proposal and/or the budget, may disqualify the offeror from consideration.

No individual or entity may serve as a consultant or subcontractor if they:

1. Had any role in suggesting, developing, or reviewing the subtopic; or
2. Have been the recipient of any information on the subtopic not available to the public.

(i) **Potential Commercial Application.** Describe in detail the commercial potential of the proposed research, how commercialization would be pursued and potentially used by the private sector and/or the Federal Government. Address the following:

(a) Market opportunity – Describe the current and anticipated target market, the

size of the market, and include a brief profile of the potential customer.

(b) Technology and competition – Describe the competitive landscape, the value proposition and competitive advantage of the product or service enabled by the proposed innovation. Also include what critical milestones must be met to get the product or process to market and the resources required to address the business opportunity.

(c) Finances – Describe your strategy for financing the innovation.

(j) **Cooperative Research and Development Agreements (CRADA)**. State if the offeror is a former or current CRADA partner with NIST, or with any other Federal agency, naming the agency, title of the CRADA, and any relationship with the proposed work. An Agency may not enter into, nor continue, a CRADA with an awardee on the subtopic of the award.

(k) **Guest Researcher**. State if the offeror or any of its consultants or subcontractors is a guest researcher at NIST, naming the sponsoring laboratory.

(l) **Cost Sharing**. Offerors may propose cost-sharing. Except where required by other statutes, NIST does not require or give preference to offerors proposing cost sharing in Phase 1. NIST will not consider whether an offeror proposes cost sharing in its evaluation of proposals

3.03.03.01 Similar Proposals or Awards

NOTE - While it is permissible, with proposal notification, to submit identical proposals or proposals containing a significant amount of essentially equivalent work for consideration under numerous Federal program solicitations, **it is unlawful to enter into funding agreements requiring essentially equivalent work**. If there is any question concerning this, it must be disclosed to the soliciting agency or agencies before award.

If a proposal submitted in response to this solicitation is substantially the same as another proposal that has been funded, is now being funded, or is pending with another Federal Agency, the proposer must so indicate on the proposal Cover Sheet and provide the following information:

(a) Name and address of all agencies to which a proposal was submitted or from which an award was received.

(b) Date of proposal submission or date of award.

(c) Title, number, and date of solicitation(s) under which a proposal was submitted or award received.

- (d) Applicable research topic(s) for each proposal submitted or award received.
- (e) Title of proposal.
- (f) Name and title of principal investigator or project manager for each proposal submitted or award received.

If no equivalent proposal is under consideration or equivalent award received, a statement to that effect **must** be included in this section of the technical content area of the proposal and certified within the Cover Sheet.

3.03.03.02 Company Commercialization History

If a small business concern has received one or more SBIR/STTR awards from any federal agency, it must submit a company commercialization history in the NIST Company Commercialization History Template (Section 8.3). **This required information shall not be part of the 25 page count limitation.** Only firms that have received prior SBIR awards from any federal agency must submit this document. Offerors are welcome to include descriptions of commercialization success for non-SBIR/STTR awards.

An SBC submitting a proposal that has received more than 15 Phase 2 SBIR awards during the last five fiscal years must document the extent to which it was able to secure Phase 3 funding to develop concepts resulting from previous Phase 2 awards. Offerors shall include this information and the commercialization history of any previous SBIR/STTR awards in the attached Commercialization History Template.

3.03.04 Proposed Budget

Complete the Proposed Budget required form (Section 8.04) for the Phase 1 effort, and include it as the last page of the proposal. Verify each line item and ensure the total request is accurate and does not exceed \$90,000. The Proposed Budget must be signed. Some items of this form may not apply to every proposal. Enough information should be provided to allow NIST to understand how the offeror plans to use the requested funds if the award is made. A complete cost breakdown should be provided giving labor rates, proposed number of hours, overhead, G&A, and profit. A reasonable profit will be allowed.

The offeror is to submit a cost estimate with detailed information for each Line Item, consistent with the offeror's cost accounting system. This does not eliminate the need to fully document and justify the amounts requested in each category. Such documentation should be contained, as appropriate, within the proposal technical content.

NIST will not issue SBIR awards that include provisions for subcontracting any portion of the contract back to the originating agency, or any other

Federal Government agency or to other units of the Federal Government without a waiver. Requests for waivers from this requirement must be sent to the contracting officer. Upon receipt, the government shall review the request and make a determination whether to forward the request to SBA for review. SBA may issue a waiver on a case-by-case basis.

For Phase 1, a minimum of two-thirds of the research and/or analytical effort must be performed by the proposing small business concern. The total cost for all consultant fees, facility leases, usage fees, and other subcontract or purchase agreements may not exceed one-third contract price. For Phase 2, a minimum of one-half of the research and/or analytical effort must be performed by the proposing small business concern.

Lines A and B, Labor. List the key personnel and consultants by name and function or role in the project. Other direct personnel need not be named, but their role, such as “technician,” and total hours should be entered. Personnel whose costs are indirect (e.g. administrative personnel) should be included in Line D. Fringe benefits can be listed for each employee in the space provided, or they may be included within the indirect costs in Line G. The PI must be employed by the small business concern at the time of contract award and during the period of performance of the research effort. Additionally, at least 51% of the PI's time must be spent with the awardee during the contract performance.

Line C, Equipment. List items costing over \$5,000 and exceeding one year of useful life. Lesser items may be shown in Line E. Indicate if equipment is to be purchased or leased. Where equipment is to be purchased or leased, list each individual item with the corresponding cost. The inclusion of equipment will be carefully reviewed relative to need and appropriateness for the research proposed.

Line D, Travel. Itemize by destination, purpose, period and cost for both staff and consultants. Budgets including travel funds must be justified and related to the needs of the project. Inclusion of travel expenses will be carefully reviewed relative to need and appropriateness for the research proposed. Foreign travel is not an appropriate expense.

Line E, Other Direct Costs. The materials and supplies, testing and/or computer services, and subcontracts required for the project must be identified. Specify type, quantity and unit cost (if applicable), and total estimated cost of these other direct costs.

Line F, Total Direct Costs. Enter the sum of Lines A through E.

Line G, Indirect Costs. Cite your established Overhead (OH) and General and Administrative (G&A) rate, if any. Otherwise include all indirect costs (e.g. facilities, shared equipment, utilities, property taxes, administrative staff) for

the period of the project. Indirect costs are costs not directly identified with a single final cost objective.

Line H, Total Costs. Enter the total amount of the proposed project, the sum of Lines F and G.

Line I, Profit. The small business concern may request a reasonable profit.

Line J, Total Amount of this request. Enter the sum of Lines H and I. This amount must equal the amount entered in the Cover Sheet Form.

Line K, Corporate/Business Authorized Representative. A signature of someone with the authority to commit the company must be given.

4.0 METHOD OF SELECTION AND EVALUATION CRITERIA

4.01 Introduction

All Phase 1 and 2 proposals will be evaluated and judged on a competitive basis. Proposals will be initially screened to determine responsiveness. Proposals passing this initial screening will be technically evaluated by engineers or scientists to determine the most promising technical and scientific approaches. Each proposal will be judged on its own merit. NIST is under no obligation to fund any proposal or any specific number of proposals in a given topic. It also may elect to fund several or none of the proposed approaches to the same topic or subtopic.

4.02 Phase 1 Screening Criteria

Phase 1 proposals that do not satisfy all the screening criteria shall be returned to the offeror without further review and will be eliminated from consideration for award. Proposals may not be resubmitted (with or without revision) under this solicitation. The screening criteria are:

- (a) The proposing firm must qualify as eligible according to the criteria set forth in [Section 1.05](#).
- (b) The Phase 1 proposal must meet **all** of the requirements stated in [Section 3.0](#).
- (c) The Phase 1 proposal must be limited to one subtopic and clearly address research for that subtopic.
- (d) Phase 1 total proposal budget must not exceed \$90,000.
- (e) The feasibility research duration for the Phase 1 project must not exceed 6 months.
- (f) The proposal must contain information sufficient to be peer reviewed as research.

4.03 Phase 1 Evaluation Criteria

Phase 1 proposals that comply with the screening criteria will undergo a two-step scored review process to achieve a strategic focus for the program, maximize investments, and facilitate commercialization.

Step 1: The proposals will be rated by NIST scientists or engineers in accordance with the following criteria:

- (a) The scientific and technical merit of the proposed research (25 points)
- (b) Innovation, originality, and feasibility of the proposed research (20 points)
- (c) Relevance and responsiveness of the proposed research to the subtopic to which it is addressed (20 points)
- (d) Quality and/or adequacy of facilities, equipment, personnel described in the proposal (15 points)
- (e) Technical assessment of the proposal's potential to result in a commercial product or service within the field of science or technology. May be supported by non-SBIR partnering commitments to further develop a product or service; or the presence of other indicators of commercial potential of the idea (20 points)

Technical reviewers will base their ratings on information contained in the proposal. It is assumed that reviewers are not acquainted with any experiments referred to, key individuals, or the firm. No technical clarifications may be made after proposal submission.

After the technical review, the superior Phase 1 proposals will be priority ranked to ensure that the proposed research is consistent with the objectives of the laboratory's research programs (<http://www.nist.gov/director/planning/planning.cfm>).

Step 2: A NIST-wide selection panel will review the content of the technically superior proposals and score them based on the following evaluation factors and develop a final ranking:

- (a) Proposal priority ranking resulting from Step 1.
- (b) The potential of the proposed research to meet NIST program priorities.
- (c) Economic impact (e.g., ability of the company to develop a commercially viable product, service or process); number and record of past performance for SBIR and STTR awards as shown in Section 3.03.03.02; consideration given to companies without

previous SBIR awards; existence of outside, non-SBIR, funding or partnering commitments; and/or the presence of other relevant supporting material contained in the proposal that indicates the commercial potential of the idea (such as letters of support, journal articles, literature, Government publications).

(d) SBIR program priorities (manufacturing-related research; energy efficiency or renewable energy; participation by minority and disadvantaged persons and HUBZones)

Final award decisions will be made by NIST based upon ratings assigned by the selection panel and consideration of additional factors such as possible duplication of other research, and the availability of funding. In the event of a “tie” between proposals, manufacturing-related projects as well as those regarding energy efficiency and renewable energy system will receive priority in the award selection process. NIST may elect to fund several or none of the proposals received on a given subtopic. Upon selection of a proposal for a Phase 1 award, NIST reserves the right to negotiate the amount of the award.

4.04 Phase 2 Evaluation Criteria

During the feasibility study project performance period, Phase 1 awardees will be provided instructions for preparation and submission of Phase 2 proposals. Phase 2 proposals that comply with the screening criteria as stated in those instructions will be rated by NIST scientists or engineers in accordance with the following criteria:

1. Degree to which Phase 1 objectives were met (25 points)
2. The scientific and technical merit of the proposed research, including innovation, originality, and feasibility (25 points)
3. Quality and/or adequacy of facilities, equipment, personnel described in the proposal (25 points)
4. Quality of the proposal’s commercialization potential as evidenced by the Commercialization Plan, the offerors record of commercializing other research products, existence of outside, non-SBIR, funding or partnering commitments, or the presence of other indicators of commercial potential of the idea. (25 points)

4.05 Release of Proposal Review Information

After final award decisions have been announced, the technical evaluations of proposals that passed the screening criteria will be provided to the offeror with written notification of award/non-award. The identity of the reviewers will not be disclosed.

5.0 CONSIDERATIONS

5.01 Awards

NIST will award firm-fixed-price purchase orders and/or contracts to successful offerors. A firm-fixed-price purchase order or contract identifies a price that is not subject to any adjustment on the basis of the contractor's cost experience in performing the effort. This agreement type places upon the contractor the risk and full responsibility for all costs and resulting profit or loss. It provides maximum incentive for the contractor to control costs and perform effectively and imposes a minimum administrative burden upon both parties. NIST also does not allow any advance payments to be made on its awards. The firm-fixed-price shall be inclusive of all transportation/shipping/insurance costs for government furnished property made available for use by awardee and all deliverables/prototypes to be furnished to NIST.

Contingent upon availability of funds, NIST anticipates making a total number of approximately 10 Phase 1 firm-fixed-price SBIR awards of no more than \$90,000 each. The total performance period shall be no more than seven (7) months beginning on the contract start date. A period of one (1) month is allotted after the six (6) month R&D duration for the awardee to prepare and submit a final report.

Phase 2 awards shall be for no more than \$300,000. The R&D activity period of performance in Phase 2 will depend upon the scope of the research, but should not exceed 25 months. One year after completing the R&D activity, the awardee shall be required to report on their commercialization activities. The total period of performance for Phase 2 is 37 months.

It is anticipated that approximately half of the Phase 1 awardees will receive Phase 2 awards, depending upon the availability of funds. To provide for an in-depth review of the Phase 1 final report and the Phase 2 proposal and commercialization plan, Phase 2 awards will be made approximately 5 months after the completion of Phase 1, contingent upon availability of funds.

This solicitation does not obligate NIST to make any awards under either Phase 1 or Phase 2. Furthermore, NIST is not responsible for any monies expended by the offerors before awards are made.

Upon award, the awardee will be required to make certain legal commitments through acceptance of numerous clauses in funding agreements. The outline that follows is illustrative of the types of clauses to which the contractor would be committed. This list is not a complete list of clauses to be included in Phase 1 funding agreements, and is not the specific wording of such clauses. Copies of complete terms and conditions are available upon request.

These statements are examples only and may vary depending upon the type of funding agreement used.

- (1) Standards of Work. Work performed under the funding agreement must conform to high professional standards.
- (2) Inspection. Work performed under the funding agreement is subject to Government inspection, evaluation, and acceptance at all times.
- (3) Examination of Records. The Comptroller General (or a duly authorized representative) must have the right to examine any pertinent records of the awardee involving transactions related to this funding agreement.
- (4) Default. The Government may terminate the funding agreement if the contractor fails to perform the work contracted.
- (5) Termination for Convenience. The funding agreement may be terminated at any time by the Government if it deems termination to be in its best interest, in which case the awardee will be compensated for work performed and for reasonable termination costs.
- (6) Disputes. Any dispute concerning the funding agreement that cannot be resolved by agreement must be decided by the contracting officer with right of appeal.
- (7) Contract Work Hours. The awardee may not require an employee to work more than 8 hours a day or 40 hours a week unless the employee is compensated accordingly (for example, overtime pay).
- (8) Equal Opportunity. The awardee will not discriminate against any employee or offeror for employment because of race, color, religion, sex, or national origin.
- (9) Affirmative Action for Veterans. The awardee will not discriminate against any employee or application for employment because he or she is a disabled veteran or veteran of the Vietnam era.
- (10) Affirmative Action for Handicapped. The awardee will not discriminate against any employee or offeror for employment because he or she is physically or mentally handicapped.
- (11) Officials Not To Benefit. No Government official must benefit personally from the SBIR funding agreement.
- (12) Covenant Against Contingent Fees. No person or agency has been employed to solicit or secure the funding agreement upon an understanding for compensation except bona fide employees or commercial agencies maintained by the awardee for the purpose of securing business.

(13) Gratuities. The funding agreement may be terminated by the Government if any gratuities have been offered to any representative of the Government to secure the award.

(14) Patent Infringement. The awardee must report each notice or claim of patent infringement based on the performance of the funding agreement.

(15) American Made Equipment and Products. When purchasing equipment or a product under the SBIR funding agreement, purchase only American-made items whenever possible.

5.02 Reports

Progress reports scheduled periodically during the Phase 1 and Phase 2 periods of performance will include all technical details regarding the research conducted up to that point in the project and will provide detailed plans for the next stages of the project. The acceptance of each progress report will be contingent upon appropriate alignment with the solicited and proposed milestones. Consideration will be given to changes from the solicited and proposed milestones if results from experimentation warrant a deviation from plan. Inclusion of proprietary information within the progress reports and final report may be necessary in order to effectively communicate progress and gain appropriate consultation from NIST experts regarding next steps. All such proprietary information will be marked according to instructions provided in [Section 5.05.03](#).

Final reports submitted under Phase 1 and Phase 2 shall include a single-page project summary as the first page, identifying the purpose of the research, and giving a brief description of the research carried out, the research findings or results, and the commercial applications of the research in a final paragraph. The remainder of the report should indicate in detail the research objectives, research work carried out, results obtained, and estimates of technical feasibility.

All final reports must carry an acknowledgment on the cover page such as: "This material is based upon work supported by the National Institute of Standards and Technology (NIST) under contract _____. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of NIST."

An R&D final report on the Phase 2 project shall be submitted to NIST within 30 calendar days after completion of the two-year Phase 2 R&D activity period. A commercialization update report on the SBIR project shall be submitted to NIST within 30 calendar days three years after the Phase 2 award date, i.e. one year after the completion of the two-year Phase 2 R&D activity period. The total period of performance for Phase 2 is 37 months.

The information provided in the Phase 2 commercialization update reports will be compiled and used as general statistics to help determine the value of the NIST SBIR

Program, educate stakeholders about the outcomes and impact, and attract new entrants.

The Phase 2 commercialization update report shall include the following:

- a. A description of the company's efforts to further develop, commercialize and derive revenues from the technology resulting from this SBIR award. These may include but are not limited to: customer/potential customer base, overview of marketing and sales strategies, other uses of knowledge gained, partners, licensing, committed resources, market readiness, use of knowledge gained for other projects, manufacturing, and financing strategy. Also discuss difficulties, and barriers to entry.

If work has ended on the project, please provide an explanation as to why (i.e. technical objective not met, existing barriers to entry, could not obtain follow-on funding, technology not economically viable, alternative technology entered the market, or other explanation).

- b. Information about any follow-on funding commitment(s) and investments to further the development and/or commercialize the Phase 2 technology.

If follow-on funding was not obtained, provide possible reasons (i.e. technical objective not met, technology not economically viable, alternative technology entered the market, or other explanation).

- c. Details about products and /or processes being developed, used for other projects, or currently in the marketplace resulting from the SBIR project.
- d. A list of any patents or published patent applications resulting from the SBIR project.
- e. Sales revenue from new products or processes received from the commercialization of this SBIR project include: sales, manufacturing, product licensing, royalties, consulting, contracts, or other.

To help assess the effectiveness of our program in meeting programmatic and SBIR objectives, NIST may periodically request information from small businesses about progress taken towards commercialization of the technology after the completion of Phase 1 and 2 contracts.

5.03 Deliverables

Offers submitted in response to subtopics that require delivery of a prototype should state in the proposal the plan to develop and deliver the specified prototype. Notwithstanding the absence of such an explicit statement in the offeror's proposal, delivery of the developed prototype as called for by the solicitation subtopic is required.

5.04 Payment Schedule

The specific payment schedule (including payment amounts) for each award will be incorporated into the purchase order and/or contract. Successful proposers may be paid periodically as work progresses in accordance with the negotiated price and payment schedule. No advance payments will be allowed.

A Phase 1 contract typically requires three progress reports that describe services performed and a final report. NIST shall make progress payments in three equal increments for the work accomplished based upon delivery by the awardee, and technical acceptance and approval by NIST of the three progress reports, and one final \$5,000 payment upon delivery and technical acceptance of the final report. The final report shall be due seven months from contract award.

A Phase 2 contract typically requires four progress reports that describe services performed, one final R&D report and prototype (if applicable per subtopic requirement), and a commercialization update report. The four progress reports are typically due at the 2nd, 6th, 12th, and 18th months of the project, the final R&D report and prototype at the 25th month, and the commercialization update report at the 37th month. NIST shall make progress payments for the award amount, minus \$5,000, to be paid in five equal increments on an interim basis upon delivery by the awardee and acceptance by NIST of the four progress reports and the final report (and prototype if applicable). The final \$5,000 shall be paid upon delivery and acceptance of the commercialization update report at the 37th month of the project. Failure to submit the report within thirteen months of the completion of the R&D activity period for Phase 2 will result in a de-obligation of the \$5,000.

5.05 Proprietary Information, Inventions, and Patents

5.05.01 Limited Rights Information and Data

Information contained in unsuccessful proposals will remain the property of the offeror. Any proposal which is funded will not be made available to the public, except for the "Project Summary" page.

The inclusion of proprietary information is discouraged unless it is necessary for the proper evaluation of the proposal. Information contained in unsuccessful proposals will remain the property of the offeror. The Government may, however, retain copies of all proposals. Public release of information in any proposal submitted will be subject to existing statutory and regulatory requirements. If proprietary information is provided by an offeror in a proposal, which constitutes a trade secret, proprietary commercial or financial information, confidential personal information or data affecting the national security, it will be treated in confidence, to the extent permitted by law. This information must be clearly marked by the offeror with the term "confidential proprietary information" and the following legend must appear on the first page of the technical section of the proposal:

"These data shall not be disclosed outside the Government and shall not be

duplicated, used, or disclosed in whole or in part for any purpose other than evaluation of this proposal. If a funding agreement is awarded to this offeror as a result of or in connection with the submission of these data, the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the funding agreement and pursuant to applicable law. This restriction does not limit the Government's right to use information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained on pages ____ of this proposal."

Any other legend may be unacceptable to the Government and may constitute grounds for removing the proposal from further consideration, without assuming any liability for inadvertent disclosure. The Government will limit dissemination of such information to within official channels.

Examples of laws that restrict the government to protect confidential/proprietary information about business operations and trade secrets possessed by any company or participant include: Freedom of Information Act (FOIA)—5 U.S.C. § 552(b); Economic Espionage Act—18 U.S.C. § 1832; and Trade Secrets Act—18 U.S.C. § 1905.

In view of the above, proposers are cautioned that proposals are likely to be less competitive if significant details are omitted due to the proposer's reluctance to reveal confidential/proprietary information.

5.05.03 Rights in Data Developed Under SBIR Contracts

To preserve the SBIR data rights of the awardee, the legend (or statements) used in the SBIR Data Rights clause included in the SBIR award must be affixed to any submissions of technical data developed under that SBIR award. If no Data Rights clause is included in the SBIR award, the following legend, at a minimum, should be affixed to any data submissions under that award:

SBIR RIGHTS NOTICE

"These SBIR data are furnished with SBIR rights under Contract No. _____ (and subcontract No. _____ if appropriate), Awardee Name _____, Address, Expiration Period of SBIR Data Rights _____. The Government may not use, modify, reproduce, release, perform, display, or disclose technical data or computer software marked with this legend for four (4) years. After expiration of the 4-year period, the Government has a royalty-free license to use, and to authorize others to use on its behalf, these data for Government purposes, and is relieved of all disclosure prohibitions and assumes no liability for unauthorized use of these data by third parties, except that any such data that is also protected and referenced under a subsequent SBIR award shall remain protected through the protection period of that subsequent SBIR award. Reproductions of these data or software must include this legend."

(END OF NOTICE)

The Government's sole obligation with respect to any properly identified SBIR data shall be as set forth in the paragraph above.

5.05.04 Patents

Small business concerns normally may retain the principal worldwide patent rights to any invention developed with Government support. The Government receives a royalty free license for Federal Government use, reserves the right to require the patent holder to license others in certain circumstances, and requires that anyone exclusively licensed to sell the invention in the United States must normally manufacture it domestically. To the extent authorized by 35 U.S.C. 205, the Government will not make public any information disclosing a Government supported invention for a minimum 4-year period (that may be extended by subsequent SBIR funding agreements) to allow the awardee a reasonable time to pursue a patent.

5.05.04.01 NIST-Owned Patented Background Inventions

SBIR awards made subsequent to "TT" subtopics in this Solicitation, will, upon the request of the awardee to a NIST licensing officer, include the grant of a non-exclusive research license to use NIST-owned patented background inventions which are specifically identified within the subtopic being awarded. SBIR offerors are hereby notified that no exclusive or non-exclusive commercialization license to make, use or sell products or services incorporating the NIST background invention is granted until an SBIR awardee applies for, negotiates and receives such a license. Awardees of solicited subtopics that identify specific NIST-owned patented background inventions will be given the opportunity to negotiate a non-exclusive commercialization license to such background inventions. If available, awardees may be given the opportunity to negotiate an exclusive commercialization license to such background inventions. License applications will be treated in accordance with Federal patent licensing regulations as provided in 37 CFR Part 404.

Any invention developed by awardee during the course of the SBIR contract period of performance is subject to the terms of Section 5.05.04.

5.05.05 Invention Reporting

SBIR awardees must report inventions to the NIST SBIR Program within 2 months of the inventor's report to the awardee. The reporting of inventions may be accomplished by submitting paper documentation, including fax or through the iEdison Invention Reporting System at www.iedison.gov.

5.06 Additional Information

(1) If there is any inconsistency between the information contained herein and the terms

of any resulting SBIR funding agreement, the terms of the funding agreement are controlling.

(2) Before award of an SBIR funding agreement, the Government may request the offeror to submit certain organizational, management, personnel, and financial information to assure responsibility of the offeror.

(3) The Government is not responsible for any monies expended by the offeror before award of any funding agreement.

(4) This program solicitation is not an offer by the Government and does not obligate the Government to make any specific number of awards. Also, awards under the SBIR Program are contingent upon the availability of funds.

(5) The SBIR Program is not a substitute for existing unsolicited proposal mechanisms. Unsolicited proposals will not be accepted under the SBIR Program in either Phase 1 or Phase 2.

(6) If an award is made pursuant to a proposal submitted under this SBIR Program solicitation, a representative of the contractor will be required to certify that the concern has not previously been, nor is currently being, paid for essentially equivalent work by any Federal agency.

(7) The responsibility for the performance of the principal investigator, and other employees or consultants who carry out the proposed work, lies with the management of the organization receiving an award.

(8) Cost-sharing is permitted for proposals under this program solicitation; however, cost-sharing is not required. Cost-sharing will not be an evaluation factor in consideration of your Phase 1 proposal.

5.07 Research Projects with Human Subjects, Human Tissue, Data or Recordings Involving Human Subjects

Protection of human subjects

Research Projects Involving Human Subjects, Human Tissue, Data or Recordings Involving Human Subjects. Any proposal that includes contractor participation in research involving human subjects, human tissue/cells, data or recordings involving human subjects must meet the requirements of the Common Rule for the Protection of Human Subjects (“Common Rule”), codified for the Department of Commerce (DoC) at 15 C.F.R. Part 27. In addition, any such proposal that includes research on these topics must be in compliance with any statutory requirements imposed upon the Department of Health and Human Services (DHHS) and other Federal agencies regarding these topics, all regulatory policies and guidance adopted by DHHS, the Food and Drug Administration, and other Federal agencies on these topics, and all Executive Orders and

Presidential statements of policy on these topics.

NIST reserves the right to make an independent determination of whether a proposer's research involves human subjects. If NIST determines that your research project involves human subjects, you will be required to provide additional information for review and approval. If an award is issued, no research activities involving human subjects shall be initiated or costs incurred under the award until the NIST Contracting Officer issues written approval. Retroactive approvals are not permitted.

NIST will accept proposals that include research activities involving human subjects that have been or will be approved by an Institutional Review Board (IRB) currently registered with the Office for Human Research Protections (OHRP) within the DHHS and that will be performed by entities possessing a currently valid Federal wide Assurance (FWA) on file from OHRP that is appropriately linked to the cognizant IRB for the protocol. NIST will not issue a single project assurance (SPA) for any IRB reviewing any human subjects protocol proposed to NIST. Information regarding how to apply for an FWA and register and IRB with OHRP can be found at <http://www.hhs.gov/ohrp/assurances/index.html>.

Generally, NIST does not fund research involving human subjects in foreign countries. NIST will consider, however, the use of **preexisting** tissue, cells, or data from a foreign source on a limited basis if all of the following criteria are satisfied:

- (1) the scientific source is considered unique,
- (2) an equivalent source is unavailable within the United States,
- (3) an alternative approach is not scientifically of equivalent merit, and
- (4) the specific use qualifies for an exemption under the Common Rule.

Any award issued by NIST is required to adhere to all Presidential policies, statutes, guidelines and regulations regarding the use of human embryonic stem cells. The DoC follows the NIH Guidelines by supporting and conducting research using only human embryonic stem cell lines that have been approved by NIH in accordance with the NIH Guidelines. Detailed information regarding NIH Guidelines for stem cells is located on the NIH Stem Cell Information website: <http://stemcells.nih.gov>. The DoC will not support or conduct any type of research that the NIH Guidelines prohibit NIH from funding. The DoC will review research using human embryonic stem cell lines that it supports and conducts in accordance with the Common Rule and NIST implementing procedures, as appropriate.

Any request to support or conduct research using human embryonic stem cell lines not currently approved by the NIH, will require that the owner, deriver or licensee of the human embryonic stem cell line apply for and receive approval of the registration of the cell line through the established NIH application procedures:

http://hescregapp.od.nih.gov/NIH_Form_2890_Login.htm. Due to the timing uncertainty associated with establishing an embryonic stem cell line in the NIH registry, the use of existing human embryonic stem cell lines in the NIH Embryonic Stem Cell Registry may

be preferred by applicants or current award recipients. The NIH Embryonic Stem Cell Registry is located at: http://grants.nih.gov/stem_cells/registry/current.htm.

A proposer or current award recipient proposing to use a registered embryonic stem cell line will be required to document an executed agreement for access to the cell line with the provider of the cell line, and acceptance of any established restrictions for use of the cell line, as may be noted in the NIH Embryonic Stem Cell Registry.

If the proposal includes exempt and/or non-exempt research activities involving human subjects the following information is required in the proposal:

- (1) The name(s) of the institution(s) where the research will be conducted;
- (2) The name(s) and institution(s) of the cognizant IRB(s), and the IRB registration number(s);
- (3) The FWA number of the applicant linked to the cognizant IRB(s);
- (4) The FWAs associated with all organizations engaged in the planned research activity linked to the cognizant IRB;
- (5) If the IRB review(s) is pending, the estimated start date for research involving human subjects;
- (6) The IRB approval date (if currently approved for exempt or non-exempt research);
- (7) If any FWAs or IRB registrations are being applied for, that should be clearly stated.

Additional documentation may be requested, as warranted, during review of the proposal, but may include the following for research activities involving human subjects that are planned in the first year of the award:

- (1) A signed (by the study principal investigator) copy of each applicable final IRB-approved protocol;
- (2) A signed and dated approval letter from the cognizant IRB(s) that includes the name of the institution housing each applicable IRB, provides the start and end dates for the approval of the research activities, and any IRB-required interim reporting or continuing review requirements;
- (3) A copy of any IRB-required application information, such as documentation of approval of special clearances (i.e. biohazard, HIPAA, etc.) conflict-of-interest letters, or special training requirements;
- (4) A brief description of what portions of the IRB submitted protocol are specifically included in the proposal submitted to NIST, if the protocol includes tasks not

applicable to the proposal, or if the protocol is supported by multiple funding sources. For protocols with multiple funding sources, NIST will not approve the study without a nonduplication-of-funding letter indicating that no other federal funds will be used to support the tasks proposed under the proposed research or ongoing project;

- (5) If a new protocol will only be submitted to an IRB if an award from NIST issued, a draft of the proposed protocol may be requested.
- (6) Any additional clarifying documentation that NIST may request during review of proposals to perform the NIST administrative review of research involving human subjects.

IRB Education Documentation

A signed and dated letter is required from the Organizational Official who is authorized to enter into commitments on behalf of the organization documenting that appropriate IRB education has been received by the Organizational Official, the IRB Coordinator or such person that coordinates the IRB documents and materials if such a person exists, the IRB Chairperson, all IRB members and all key personnel associated with the proposal. The NIST requirement of documentation of education is consistent with NIH notice OD-00-039 (June 5, 2000). Although NIST will not endorse an educational curriculum, there are several curricula that are available to organizations and investigators which may be found at:

<http://grants.nih.gov/grants/guide/notice-files/NOT-OD-00-039.html>.

5.08 Research Projects Involving Vertebrate Animals

Any proposal that includes research involving live vertebrate animals must be in compliance with the National Research Council's "Guide for the Care and Use of Laboratory Animals," which can be obtained from National Academy Press, 500 5th Street, N.W., Department 285, Washington, DC 20055. In addition, such proposals must meet the requirements of the Animal Welfare Act (7 U.S.C. § 2131 et seq.), 9 C.F.R. Parts 1, 2, and 3, and if appropriate, 21 C.F.R. Part 58. These regulations do not apply to proposed research using **preexisting** images of animals or to research plans that do not include live animals that are being cared for, euthanized, or used by the project participants to accomplish research goals, teaching, or testing. These regulations also do not apply to obtaining animal materials from commercial processors of animal products or to animal cell lines or tissues from tissue banks.

NIST reserves the right to make an independent determination of whether your research involves live vertebrate animals. If NIST determines that your research project involves live vertebrate animals, you will be required to provide additional information for review and approval. If an award is issued, no research activities involving live vertebrate animals subjects shall be initiated or costs incurred under the award until the NIST Contracting Officer issues written approval.

If the proposal includes research activities involving live vertebrate animals the following information is required in the proposal:

- (1) The name(s) of the institution(s) where the animal research will be conducted;
- (2) The assurance type and number, as applicable, for the cognizant IACUC where the research activity is located. [For example: Animal Welfare Assurance from the Office of Laboratory Animal Welfare (OLAW) should be indicated by the OLAW assurance number, i.e. A-1234; an USDA Animal Welfare Act certification should be indicated by the certification number i.e. 12-R-3456; and an Association for the Assessment and Accreditation of Laboratory Animal Care (AAALAC) should be indicated by AAALAC.]
- (3) The IACUC approval date (if currently approved);
- (4) If the review by the cognizant Institutional Animal Care and Use Committee (IACUC) is pending, the estimated start date for research involving vertebrate animals;
- (5) If any assurances or IACUCs need to be obtained or established, that should be clearly stated.

Additional documentation will be requested, as warranted, during review of the proposal, but may include the following for research activities involving live vertebrate animals that are planned in the first year of the award:

- (1) A signed (by the Principal Investigator) copy of the IACUC approved Animal Study Proposal (ASP);
- (2) Documentation of the IACUC approval indicating the approval and expiration dates of the ASP; and
- (3) If applicable, a nonduplication-of-funding letter if the ASP is funded from several sources.
- (4) If a new ASP will only be submitted to an IACUC if an award from NIST issued, a draft of the proposed ASP may be requested.
- (5) Any additional clarifying documentation that NIST may request during review of proposals to perform the NIST administrative review of research involving live vertebrate animals.

5.09 Technical Assistance for Proposal Preparation and Project Conduct

Proposers may wish to contact the NIST Hollings Manufacturing Extension Partnership (MEP), a nationwide network of locally managed extension centers whose sole purpose is

to provide small- and medium-sized manufacturers with the help they need to succeed. The centers provide guidance to high-technology companies seeking resources and teaming relationships. To contact an MEP center, call 1-800-MEP-4-MFG (1-800-637-4634) or visit MEP's website at www.mep.nist.gov.

MEP Centers are also prepared to provide referrals to state and local organizations offering resources and technical assistance to all NIST SIBR proposers after award solicitations have been announced. If you would like your local MEP Center to contact you, please check the box on page 2 of the cover sheet.

6.0 SUBMISSION OF PROPOSALS

6.01 Deadline for Proposals

Deadline for Phase 1 SBIR proposal receipt is 3:00 pm on Friday, March 2, 2012 at the Contracts Office address below.

NIST does not accept electronic submission of proposals.

NIST will not evaluate proposals received after the stated deadline or that do not adhere to the other requirements of this solicitation (see checklist in section 8.05). [Federal Acquisition Regulation](#) (FAR 52 215-1) regarding late proposals shall apply.

All Offerors should expect delay in delivery due to added security at NIST. It is the responsibility of the Offeror to make sure delivery is made on time.

Because of the heightened security at NIST, USPS, FED-EX, UPS or similar-type service is the preferred method of delivery of proposals.

If proposals are to be hand delivered prior to the due date, delivery must be made by the actual deadline date and a 24-hour notice must be made to the NIST Contracts Office prior to delivery. All Offerors must notify Micole Cheatham at 301-975-8335 or mcheath@nist.gov. The name of the individual or courier company making the delivery must be included in the notification.

Offerors are cautioned to be careful of unforeseen delays, which can cause late arrival of proposals at NIST, resulting in them not being included in the evaluation procedures.

No information on the status of proposals under scientific/technical evaluation will be available until formal notification is made.

6.02 Proposal Submission

If **courier delivered**, the Offeror must submit the Proposal Packages (**four (4) copies**) as defined in [Section 3.03](#) to:

National Institute of Standards and Technology
Acquisitions and Management Division
Attn: Micole Cheatham, NIST-12-SBIR
100 Bureau Drive STOP 1640 Building 301, Room B125
Gaithersburg, MD 20899-1640

Telephone: (301) 975-8335

Hand delivery will be accepted ONLY at the following location on the due date, Friday, March 2, 2012, from 8:00 AM EST until closing time at 3:00 PM EST:

National Institute of Standards and Technology
100 Bureau Drive (Off Clopper Road)
Visitor Center ONLY
Gaithersburg, MD 20899

Photocopies will be accepted.

Acknowledgment of receipt of a proposal by NIST will be made. All correspondence relating to proposals must cite the specific proposal number identified on the acknowledgment.

(a) Packaging--Secure packaging is mandatory. NIST cannot process proposals damaged in transit. All 4 copies of the proposal must be sent in the same package. Do not send separate "information copies," or several packages containing parts of a single proposal, or two packages of 4 copies of the same proposal. **Clearly mark the bottom right-hand corner of the package with the subtopic number to which the proposal is responding.**

(b) Bindings--Do not use special bindings or covers. Staple the pages in the upper left hand corner of each proposal. Separation or loss of proposal pages cannot be the responsibility of NIST.

7.0 SCIENTIFIC AND TECHNICAL INFORMATION SOURCES

Background information related to the NIST research programs referenced within the subtopics may be found within the NIST website at: www.nist.gov. The NIST Virtual Library, <http://nvl.nist.gov/> may also provide valuable scientific and technical information resources. Wherever possible, reference citations are provided within the individual subtopics.

8.0 SUBMISSION FORMS

8.01 Click on this link: [Cover Sheet](#) in order to access the required form (2 pages) in pdf format.

8.02 Click on this link: [Project Summary](#) in order to access the required form in pdf format.

8.03 Click on this link: [Company Commercialization History](#) Template

8.04 Click on this link: [Proposed Budget](#) in order to access the required form in pdf format.

8.05 Checklist of Requirements

Please review this checklist carefully to assure that your proposal meets the NIST requirements. Failure to meet these screening requirements will result in your proposal being returned without consideration. **Four copies of the proposal must be received by 3:00p.m. EST March 2, 2012.**

1. The [Cover Sheet](#) (both pages combined count as one toward page count) has been completed and is page 1 of the proposal. Required signatures on page 1-b are included.
2. The [Project Summary](#) is page 2 of the proposal. The abstract contains no proprietary information.
3. The Technical Content of the proposal begins on page 3 and includes the items identified in [Section 3.03.03](#) of the solicitation. The technical content section of the proposal is limited to 22 pages in length.
4. The [Company Commercialization History](#) is required only for firms that have received prior SBIR/STTR awards from any federal agency. **This document shall not be part of the 25 page count limitation.**
5. The [Proposed Budget](#) has been completed, including signature, and is the last page of the proposal. The proposal budget is for \$90,000 or less. No more than one-third of the budget is allocated to consultants and/or subcontractors.
6. The entire proposal, including forms and the technical content, is 25 pages or less in length.
7. The proposal is limited to only one of the subtopics in Section 9.
8. The proposal contains only pages of 21.6cm X 27.9cm size (8 ½" X 11").
9. The proposal contains an easy-to-read font (fixed pitch of 12 or fewer characters per inch or proportional font of point size 10 or larger) with no more than 6 lines per inch, except as a legend on reduced drawings, but not tables.
10. The P.I. will be employed by the company at least 51% time during the award period.

11. If proposal addresses a subtopic that depends on patented background NIST technology, a non-exclusive, royalty-free patent license [application](#) is required. One signed original application is to be sent with the proposal package. Each subtopic that references patented background technology and requires a license application is denoted with an asterisk.

NOTE: Offerors are cautioned to be careful of unforeseen delays that can cause late arrival of proposals, with the result that they **WILL NOT** be forwarded for evaluation.

Potential offerors are advised to sign up within <http://www.fedbizopps.gov> to receive notification of any amendment to the solicitation that may be released after opening date. Also, potential offerors are advised to check the public Q&A website located at <http://www.nist.gov/sbir> for up-to-date information concerning specific subtopics that may be posted during the Solicitation open period.

9.0 RESEARCH TOPIC AREAS

The research topic areas are aligned with NIST's investment priority areas identified in NIST's Three-Year Programmatic Plan: <http://www.nist.gov/director/planning/planning.cfm>.

9.01 Information Technology & Cybersecurity

9.01.01.68-R High-Power, High-Speed Photodiodes

NIST has developed a novel photonic approach to generating ultralow phase noise microwave signals in the range of 10 GHz. The basic architecture of the photonic microwave generator includes: (1) a continuous-wave (CW) laser that is frequency-stabilized to an ultra-stable optical cavity, (2) a self-referenced mode-locked laser that is phase-locked to the CW laser, and (3) a photodiode detecting the mode-locked laser repetition rate. Such an approach can have a significant advantage over more conventional electronic approaches in terms of phase noise. It will benefit advanced information and communication technology applications, such as in radar, microwave photonics, navigation, and atomic clocks.

While all components of the system contribute to the achievable phase noise floor, a recent focus has been on the noise that arises in the conversion of an ultrastable optical pulse train to an electronic microwave signal in the photodiode. When the optical signals are detected and coupled to electronics, the phase noise can be degraded due to the conversion of amplitude noise to phase noise, photodiode saturation, intrinsic $1/f$ noise in the photodiode, and fundamental photodiode shot noise.

To address these issues, NIST is soliciting proposals for developing advanced photodiodes that can achieve the highest possible timing precision in detecting ultra-short pulses from mode-locked lasers. The lasers of interest operate in the range of 980 nm to 1560 nm and emit sub-picosecond pulse trains at rates of 250 MHz to 5

GHz. Desired properties (the specifications) of the advanced photodiodes include the following:

- Operation in the wavelength range: 980 nm – 1560 nm
- Operation with subpicosecond optical pulses at repetition rates of 250 MHz to 5 GHz
- Average photocurrent: >50 mA and as high as possible
- Output microwave power (e.g. at 10 GHz) with pulsed illumination: > +15 dBm
- Bandwidth: 10 GHz – 50 GHz
- Responsivity: >0.5 A/W @ 1550 nm, and >0.4 A/W @ 980 nm
- AM-to-PM conversion: < 0.1 rad (at 10 GHz) per fractional change in optical power (see ref. [5])
- 1/f noise: $L(f) < -120$ dBc/Hz at 10 GHz
- Single-mode-fiber coupled and packaged with co-axial microwave output connector.

Phase 1 Activities and Deliverables:

- Develop advanced photodiodes that can achieve the highest possible timing precision in detecting ultra-short pulses from mode-locked lasers, approaching the properties as described above. We realize that the combination of all of these properties is very challenging and it is not expected that all of them can be achieved together in Phase 1. Most interesting in Phase 1 will be devices that address the requirements of high average current, high microwave power, and low AM-to-PM conversion. However, proposers should focus on novel technology that would be most promising for ultimately leading to devices that would meet all the specifications.
- At least four packaged photodiodes must be delivered to NIST at the end of Phase 1 for evaluation.

Phase 2 Activities and Deliverables:

- Produce advanced photodiodes that achieve or exceed the specifications described above.

- At least eight packaged photodiodes must be delivered to NIST at the end of Phase 2 for evaluation.

NIST is willing to provide laboratory resources and personnel to aid in the testing and evaluation of the deliverables throughout each of the respective phases, and to provide consultation, input, and discussion with the successful awardee as appropriate to the award goals.

References:

- [1] A. Bartels, S.A. Diddams, C.W. Oates, G. Wilpers, J. C. Bergquist, W. Oskay, L. Hollberg, "Femtosecond laser based synthesis of ultrastable microwave signals from optical frequency references," *Opt Lett.* 30, 667 (2005).
- [2] J.J. McFerran et al., Low noise synthesis of microwave signals from an optical source *Electron. Lett.* 41, 36 (2005).
- [3] E.N. Ivanov, S.A. Diddams, and L. Hollberg, "Study of Excess Noise Associated with Demodulation of Ultra-Short Infrared Pulses," *IEEE T. Ultrason. Ferr.* 52, 1068 (2005).
- [4] T. Fortier, M. Kirchner, F. Quinlan, J. Taylor, J.C. Bergquist, Y. Jiang, A. Ludlow, C.W. Oates, T. Rosenband, and S.A. Diddams, "Generation of ultrastable microwaves via optical frequency division," *Nature Photonics* 5, 425 (2010).
- [5] J. Taylor, S. Datta, A. Hati, C. Nelson, F. Quinlan, A. Joshi, and S. Diddams, "Characterization of Power-to-Phase Conversion in High-Speed P-I-N Photodiodes," *IEEE Photonics Journal* 3, 140 (2011).

9.01.02.68-R Microfabricated High-Frequency Connectors for Millimeter-Wave Technology

Developing information and communications technologies at frequencies above 110 GHz is hampered by a lack of broadband connectors both for system integration and test. Current microwave coaxial connectors are fabricated in machine shops, are costly, and are limited as to the frequencies at which they can be used. Current commercially available coaxial connectors are limited to about 110 GHz.

Large-signal network analyzers provide a motivation for this project. They are effective new measurement tools that allow circuit designers to "see" the voltages and currents in their design directly, and are an indispensable tool for optimizing nonlinearity and efficiency in transmitter electronics to increase dynamic range and battery life. While large-signal network analyzers are becoming common place at cellular and microwave frequencies, accurate large-signal device characterization at millimeter-wave frequencies will require a new connector type that is broadband enough to simultaneously capture fundamental frequencies and harmonics and flexible enough to allow conventional instrumentation to be integrated into the test sets.

Rectacoax (a.k.a. recta-coax, the better Google search term) transmission lines are microfabricated transmission lines similar to coaxial transmission lines. They are fabricated with a planar process that produces a stack of many planar patterned metal layers, and can be fabricated in large batches. Like coaxial transmission lines, they have a central hollow metal enclosure with a metal center conductor suspended in the center. Due to the fabrication technology, rectacoax transmission lines have a rectangular cross section, but are electrically quite similar electrically to coaxial transmission lines. However, rectacoax transmission lines can be easily fabricated in much smaller sizes, supporting single-mode propagation from dc to many hundreds of GHz, which is not possible with conventional machined coaxial connectors. They can also be batch-fabricated with modern micro-fabrication technologies. However, rectacoax transmission lines in and of themselves are not adequate for most applications, which required connectors that allow rectacoax transmission lines to be disconnected and reconnected repeatably.

This project is to develop and commercialize a new series of high-frequency microfabricated rectangular metal “recta-coax” connectors, adapters, wafer probes, and chip holders to enable electronic millimeter-wave measurement instrumentation. This project will develop these new connector type for testing and other development purpose, demonstrate an instrument for large-signal device characterization at millimeter-wave frequencies, and, if fully successful, pave the way for the introduction of these connectors as a batch-manufacturable commercial product.

Proposals for this project should discuss the manufacturability aspects of the processes they propose. They should also specify how they plan to meet or exceed the return loss and repeatability specifications required for phase 1 success, including specifying how they will achieve the electrical and mechanical material properties required to achieve repeatable connections and disconnections. Applicants should also specify how they will work with NIST on electrical design and on the incorporation of NIST chips in the designs, and present plans for commercializing the connectors and adaptors developed on this program should the approach be fully successful.

Phase 1 Activities and Deliverables:

Phase 1 will demonstrate the feasibility of rectacoax connectors.

- Awardees must demonstrate the ability to connect and disconnect rectacoax connectors at least five times with a return loss of -15 dB and a repeatability of at least -30 dB over a 50 GHz bandwidth. Verification of this performance metric must be performed at NIST.
- Awardees may also fabricate prototypes of the adapters, probes, and circuits that will be required in Phase 2, but do not have to demonstrate their performance.

Phase 2 Activities and Deliverables:

Phase 2 will further refine the connectors, add a full line of adapters, and fabricate the components needed to build a large-signal network analyzer for use at fundamental frequencies to 138 GHz that captures harmonics to 420 GHz.

- Awardees must demonstrate at least 20 reproducible connections and disconnections between two rectacoax connectors with a return loss of -25 dB and a repeatability of -30 dB over a 420 GHz single-mode bandwidth. To accomplish this, offerors must also fabricate a set of rectacoax to rectangular waveguide adapters covering the band 110 GHz to 420 GHz. Final verification of this performance metric must be performed at NIST.
- Awardees must also fabricate a chip holder designed to hold NIST electro-optic samplers with CPW inputs and holes to allow access for the required optical sampling beams. These components are extremely linear and have great dynamic range, and will be used at NIST to demonstrate feasibility of a large-signal network analyzer and other measurement instruments based on this technology for use at fundamental frequencies to 138 GHz that captures harmonics to 420 GHz.

NIST has a network analysis measurement capability to 750 GHz that will be used to verify final performance metrics. Applicants are encouraged to propose ways of working with NIST to accomplish not only the measurements required to verify the electrical performance of the deliverables, but also measurements that may help them to quantify the performance of various prototypes. Applicants are also encouraged but not required to propose a working relationship with NIST on the electrical aspects of the designs, but are expected to perform all aspects of the mechanical design tasks themselves.

9.01.03.68-R Ultrafast Photodetector for Probing Coplanar Waveguide Electrical Circuits

Optoelectronic devices are a cost effective method for generating high speed, low jitter electrical pulses for probing high-speed electrical circuits. This technology becomes particularly appealing when operating in the 1550 nm telecommunications band.

The challenge is to convert the optical signal to an electrical signal and to couple the electrical signal efficiently and with low distortion to an ultrafast circuit for testing the circuit. Commercially available photodiodes and 1.0 mm coax to coplanar waveguide (CPW) probes are limited in single-mode bandwidth to 110 GHz. However, the technology exists to build probes that operate at several hundred GHz.

We seek a probe that merges the high bandwidth of optoelectronic technology with the flexibility of a CPW probe, to generate electrical pulses with bandwidth greater than 200 GHz and to launch them into a CPW circuit with nominal 50 ohm impedance. The goal of this project is to build a device that converts a 1550 nm optical impulse to

an electrical impulse with 200 GHz bandwidth and which couples the electrical impulse to a CPW circuit.

The coupling should have low loss and low distortion from DC to greater than 200 GHz. The device should be compact and mountable on standard CPW probe stages. The device should be capable of making repeated contacts with various CPW circuits. The optical to electrical conversion efficiency should be comparable to commercially available photodiodes, i.e., 0.1 A/W or more, and generate 100 mV peak voltage on a 50 Ohm load with less than 20 mW peak optical power.

High efficiency devices operating at 775 nm will also be considered, but must be extremely efficient to compensate for the low power available for a frequency doubled Er-doped fiber laser. Successful proposals will address both the design of the optoelectronic converter and the reusable interconnect between the converter and a CPW circuit.

Phase 1 Activities and Deliverables:

- Deliver five devices to NIST for evaluation. Devices should provide at least 100 GHz bandwidth.
- Provide a viable plan for achieving a device bandwidth of at least 200 GHz.

Phase 2 Activities and Deliverables:

- Improve design in terms of bandwidth, coupling efficiency, and optical responsivity.
- Deliver 10 refined devices to NIST.

NIST is willing to work collaboratively with the awardee on the test and evaluation of prototype devices.

References:

1. D. F. Williams, P. D. Hale, and T. S. Clement, "Calibrated 200 GHz waveform measurement," IEEE Trans. Microwave Theory Tech., Vol. 53, pp.1384–1389 (April 2005).
2. D. F. Williams, P. D. Hale, T. S. Clement, and J. M. Morgan, "Calibrating electro-optic sampling systems," IMS Conference Digest, pp. 1527–1530, (May 2001).

9.01.04.77-TT WS-BiometricDevices (WS-BD) Conformant Handheld Fingerprint Sensor

The Internet is a system that most every computer and mobile device understands. The National Institute of Standards and Technology's (NIST) *Special Publication 500-288* is a *Specification for WS-BiometricDevices (WS-BD)*, which brings the Internet to biometric acquisition devices via web services. WS-BD offers a RESTful web service-based framework for communicating and controlling the operation of a biometric acquisition device. Currently, no biometric acquisition device exists which has web-enabled communication and control based on a publicly available specification.

NIST seeks innovative proposals for the design and development of a small form-factor, tamper-resistant, and handheld fingerprint (at minimum) sensor with a self-contained battery/power source, and an integrated, wirelessly available (IEEE 802.11) WS-BD service. Additionally, the device must include a physical connection for customization of the wireless controls and service. The physical connection can be USB or other; if "other" is chosen, approval of connection type by NIST is required.

The *Specification for WS-BiometricDevices (WS-BD)* and NIST's reference implementation was developed at NIST by employees of the Federal Government in the course of their official duties. Pursuant to Title 17 Section 105 of the United States Code, this software is not subject to copyright protection and is in the public domain.

Should the proposal be awarded, the applicant should expect to collaborate with NIST to further refine the phases to better reflect the particular activity proposed.

The goal of this project is to have a fully functional, handheld device, capable of biometric acquisition, and controlled through web services as specified in NIST Special Publication 500-288.

Phase 1 Activities and Deliverables:

- Kickoff Meeting within one (1) month of award
- Bimonthly status reports (reports may be followed by discussion)
- Technical specifications of the device
- Engineering drawings of the device (include dimensions and measurements)
- Partially implemented software stack targeting the platform which will be used in the device (must provide evidence of basic functionality).

Phase 2 Activities and Deliverables:

- Kickoff meeting within one (1) month of award
- Bimonthly status reports (reports may be followed by discussion)
- WS-BD Device with integrated single fingerprint sensor
- It is encouraged that a second device be developed incorporating a modality (or modalities) from the list below:
 - Face
 - Slap Fingerprint (must not be on the same device as the single fingerprint sensor)
 - Iris

NIST will be available to be contacted for consultation, input, and discussion.

Reference:

NIST Special Publication 500-288 – Specification for WS-BiometricDevices (WS-BD), <http://bws.nist.gov/>.

9.02 Manufacturing

9.02.01.63-R Development of a Microcompressor for Miniaturized Cryocooling

Most refrigeration processes, whether at cryogenic temperatures or near room temperature, rely on the compression of a gaseous working fluid. Cooling occurs when the fluid is expanded at some other location in the refrigeration system. Reduced temperatures improve the performance of many devices, such as photon detectors (terahertz, infrared, X-ray, and gamma ray), low noise amplifiers, inertial sensors, filters, and processors (computers). Some of the most sensitive devices utilize superconductivity, which requires temperatures below about 80 K. In the past decade or so, these devices have been significantly miniaturized to allow for hand-held applications. In the case of processors, the ever-decreasing chip size and high packing density has led to severe problems of heat removal. The ability to move a cold fluid through small channels can significantly improve the heat removal in such applications. Refrigeration powers of only 10 to 100 mW are now becoming typical for cooling some of the latest micro-electronic devices to temperatures in the range of 70 to 200 K. Input powers for such refrigerators can be less than about 1 W, if high efficiency is achieved. Existing refrigeration devices have not kept pace with the electronic devices in terms of miniaturization. The main bottleneck in the miniaturization is the compressor. A compressor to provide a pressure ratio of at least 5 is required either for a vapor-compression refrigerator (near ambient temperatures) or for a Joule-Thomson refrigerator (cryogenic temperatures). The smallest commercial compressors require tens of watts of input power and are designed for refrigeration powers of many watts.

The University of Colorado and NIST have recently developed microscale cold heads for a mixed-refrigerant Joule-Thomson cryocooler. The heat exchanger and expansion impedance occupy only a few cubic millimeters. One type uses hollow glass fibers for the heat exchanger and the other uses a planar polyimide heat exchanger fabricated with MEMS techniques. They are being powered with a modified commercial compressor, which is an order of magnitude larger than necessary. A MEMS-fabricated compressor would be an ideal match for such cold heads. A pressure ratio of at least 5 at a flow rate of 10 to 100 standard cubic centimeters per minute (sccm) is required for most of the applications discussed here. Currently, the highest pressure ratio achieved in a MEMS-fabricated compressor has been about 2. At a pressure ratio of 5 and a flow rate of 30 sccm, an ideal isothermal compressor power of 90 mW is required. An isothermal compressor efficiency of at least 10 % is desired to keep the input power low enough for operation with small batteries. A compressor volume of less than about 5 cm³ for a flow rate of 30 sccm would be desirable for these applications and be consistent with the size of the cold head.

A wafer-level fabrication technology like that used for MEMS devices is ideal for reducing manufacturing costs. The compressor cost tends to dominate the cost of most refrigeration systems. For a specified flow rate, the compressor swept volume is inversely proportional to the operating frequency. Thus, high frequency operation is desirable for such microcompressors. The only frequency limitation would be that at which efficiency or lifetime begins to decrease significantly. The proposed fabrication technology should be one that has the potential for lifetimes of at least one year in continuous operation and low manufacturing costs for many commercial applications.

The goal of this project will be to produce and demonstrate a microprocessor design and prototype, which can in principle be produced via wafer-level fabrication techniques. The result should be a microcompressor with a pressure ratio of at least 5, with a flow rate of 30 standard cubic centimeters per minute, with a volume of less than 5 cubic centimeters, and with at least 10 % operating efficiency. The device also needs to be economically viable to produce and have long lifetime (at least one year of continuous operation).

Phase 1 Activities and Deliverables:

- Develop a model of the microcompressor, which is then used to show the flow rate, delivered fluid power, and input power as a function of the pressure ratio. A pressure ratio of 5 at a flow rate of 30 sccm with nitrogen gas is to be achieved with an input power less than 1 W. The inlet pressure is assumed to be 1 atmosphere.
- Develop a wafer-level fabrication plan for the microcompressor.
- Provide a solid model of the microcompressor, and show that the total volume (neglecting electronics) is less than 5 cm³.

- Develop a commercialization plan for the microcompressor.

Phase 2 Activities and Deliverables:

- Construct and demonstrate a prototype of the microcompressor. Show that the device provides a flow of 30 sccm at a pressure ratio of 5 using less than 1 W of input power.
- Conduct measurements of flow rate and input power as a function of pressure ratio.
- Provide a written report describing all fabrication processes and measurements.
- Demonstration of the device to the NIST Technical Representative.

During Phase 1, NIST staff will be available to address questions about the NIST cryocooler technology and cold head designs. In addition, NIST staff will be able to assist in testing the solid model of the microprocessor. During Phase 2, NIST staff will be able to assist in testing the prototype microcompressor.

Reference:

R. Lewis, Y. Wang, J. Cooper, M.M. Lin, V.M. Bright, Y.C. Lee, P. Bradley, R. Radebaugh, and M. Huber, "Micro Cryogenic Coolers for IR Imaging," *Infrared Technology and Applications XXXVII*, Proc. of SPIE (2011).

9.02.02.68-TT High-Precision, Random Profile Roughness Specimens

This project aims to develop high-precision, random profile roughness specimens with roughness average Ra [1,2] ranging from 0.01 μm , to 0.05 μm , to 0.1 μm to support the quality control of smooth engineering surfaces for U.S. manufacturing industries.

The initial random profile roughness specimen was invented by PTB (Physikalisch-Technische Bundesanstalt, Germany) in 1964. The PTB specimens have repeat uni-directional random profiles with high repeatability, which allows the user to measure essentially the same random profile pattern anywhere on the surface. The PTB specimens were manufactured with a profile repetition of 4 mm and Ra ranging from 0.15 μm , to 0.5 μm , to 1.5 μm , which could be used for the quality control of medium machined engineering surfaces within the same Ra range. The PTB specimens were written in the International Standard ISO 5436 in 1985 [1] and the U.S. National Standard ASME B46 in 1995 [2].

With the development of modern science and technology, the quality control for smooth engineering surfaces ($Ra < 0.1 \mu\text{m}$) becomes increasingly important, not only because of their important engineering functions, but also the high production costs. NIST has frequently received requests from U.S. industry to provide Standard

Reference Material (SRM) high-precision, random profile roughness specimens to support smooth surface measurements. In 1995, the high-precision random profile roughness specimens with Ra ranging from 0.01 μm , to 0.05 μm , to 0.1 μm were written in the U.S. National Standard ASME B46-1995 [2]. The prototype high-precision random profile roughness specimens were initially designed and manufactured in 1985 and were described in publication in 1988 [3] (see Figure 1). They have been frequently referred in literature, including Prof. T.R. Thomas' renowned book "Rough Surfaces" in 1999 [4].

The high-precision, random profile roughness specimens are designed to exceed the PTB specimens with the following characteristics (see Figure 1):

- The profile repetition is 0.4 mm and 1.25 mm; the roughness average Ra range is from 0.01 μm , to 0.05 μm , to 0.1 μm , which is less than 10 % of the Ra range of PTB specimens.
- A smooth reference surface with Ra less than 0.003 μm is located on the mean lines of the random profiles (see Figure 1), which can provide a reference datum for roughness measurements and profile comparisons for smooth engineering surfaces [3,4].
- The micro hardness ($\text{HV} \geq 850$) is higher than the PTB specimens ($\text{HV} \geq 700$) [3]. That is helpful for the high precision measurements and long term of use of these specimens.

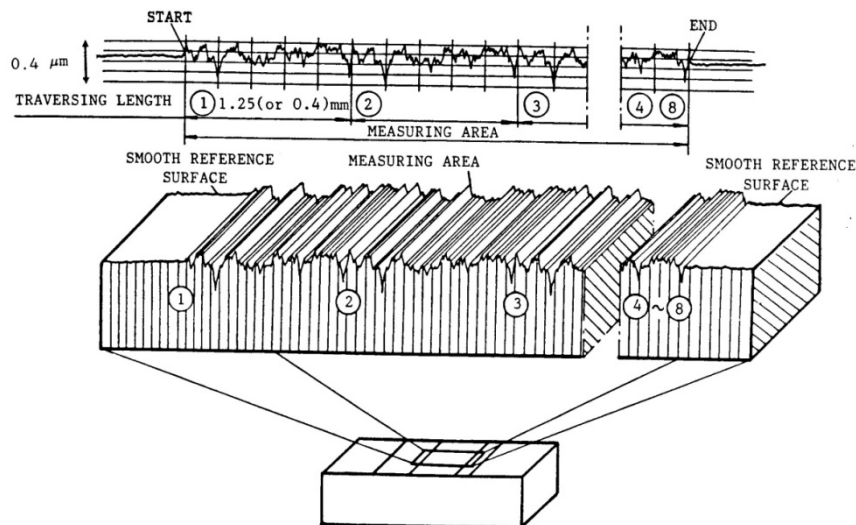


Figure 1: The high-precision, random profile roughness specimen [3,4].

This project aims to further develop and produce for commercial sale high-precision, random profile roughness specimens. These are intended for use as calibration and

check standards for stylus and optical instruments to measure smooth engineering surfaces. If this project is successful, NIST may procure specimens for Standard Reference Materials (SRMs), which are certified by NIST and sold as calibration standards.

Phase 1 Activities and Deliverables:

- Demonstrate feasibility of using the innovative manufacturing process developed by Song [3] to produce the high-precision, random profile roughness specimens with repeat uni-directional random profiles and smooth reference surfaces, and with high profile repeatability.
- Produce test samples for demonstrating the profile repeatability by profile measurements and correlations using the NIST surface calibration system and NIST 2D and 3D topography measurement system.

Phase 2 Activities and Deliverables:

- Establish a functional production line for the production of the specimens.
- Produce prototype high-precision, random profile roughness specimens with profile repetition of 0.4 mm and 1.25 mm, roughness average Ra of 0.01 μm , 0.05 μm , and 0.1 μm , and with smooth reference surfaces of Ra = 0.003 μm located on the profile mean lines [3,4].
- At least three sets of prototypes must be produced for NIST measurements and tests.

The awardee would work collaboratively with NIST staff members to:

- Transfer the innovative manufacturing technique
- Establish a functional production line
- Measure and inspect specimens using a contact stylus instrument and a non-contact optical microscope, as well as 2D and 3D topography measurement systems.

References:

[1] ISO 5436-1985 (E), Calibration specimens – Stylus instruments – Types, calibration and use of specimens, ISO, Geneva, 1985.

[2] ASME B46-1995, Surface texture: roughness waviness and lay, ASME, New York, 1995.

[3] J. Song, High-precision Random Profile Roughness Specimens, Surface Topography, Vol. 1, No. 3, September 1988, pp. 303–314.

[4] T. R. Thomas, Rough Surfaces (Second Edition), Imperial College Press, London, 1999, pp 28–29.

9.02.03.73-R Low-cost Stabilized Diode Lasers for Displacement Measurements

Non-contact, high-resolution, relatively long-range (up to 100mm) displacement measuring devices with small footprint are needed for performance characterization of micro-manufacturing equipment and processes. Typically, displacement measurements are done using laser interferometers utilizing well controlled gaseous laser sources (e.g. HeNe) providing stable and traceable laser wavelength. However, such laser sources are too large and cumbersome to use in equipment aimed at manufacturing micro-scale parts and features. With the advent of solid-state diode lasers, there is an opportunity to incorporate displacement measurements into the micro-scale equipment if they can provide stable laser frequencies. Therefore, this subtopic is addressing the development of low-cost stabilized diode lasers for displacement measurements for manufacturing applications.

The goal is to develop low-cost stabilized diode laser as a light source for interferometric displacement measurements.

Phase 1 Activities and Deliverables:

Development of proof of concept with:

- Test of inexpensive temperature control system to enable frequency stabilization
- Stabilization with coarse and fine frequency control
- Test of laboratory prototype and comparing against the HeNe laser interferometers

Phase 2 Activities and Deliverables:

- Miniaturization of interferometer cavities
- Development of robust packaging that would meet shop floor environmental conditions (temperature and vibration)
- Field testing on machine tools and comparing against HeNe laser interferometers by the awardee (NIST may provide access to its various machine tools if necessary)

- Comparison to iodine stabilized laser sources
- Marketing analysis and plans

NIST would like to work collaboratively with the awardee.

9.02.04.63-R Non-contact Microwave Measurement of Electrical Properties of Nanofiber Materials

Functional nanofiber materials made of carbon nanotubes, modified ceramics, and electrically modified polymeric resins are currently being developed for use in a wide range of applications. Carbon nanotubes in particular have recently been utilized to improve the mechanical and heat transfer characteristics, electromagnetic shielding, and to enhance the electrical conductivity of the resulting composites. Electrical characteristics, such as alternating current (AC) complex conductivity and dielectric permittivity are the key functional parameters of these materials. Electrical property measurement can be used for assessment of the materials quality and for controlling the manufacturing process.

NIST has developed a testing methodology capable of monitoring the complex AC impedance of thin dielectric and semiconducting films at microwave frequencies. The NIST procedure involves the measurement and analysis of the scattering wave parameters (S-parameters). This procedure takes into consideration the wave propagation effect in the specimen section. The specimen is treated as a transmission line of a certain electrical length. At low frequencies, the propagation model simplifies to an expression for the input admittance of a transmission line terminated with a lumped shunt capacitance. At higher frequencies, the testing methodology accounts for the wave propagation in the specimen, and eliminates systematic uncertainties of the lumped element approximation. This approach allows for the accurate determination of the complex impedance of the specimen at microwave frequencies. The results depend on the specimen's lateral dimensions, residual inductance and its complex permittivity. In this testing methodology, the boundary conditions for the propagating electromagnetic wave are determined by the conducting electrodes that are in contact with the specimen.

An accurate contact method for characterizing the complex permittivity of materials by measuring their complex impedance has been developed. However, this method requires a small sample to be removed from the batch of material and very carefully prepared for testing. Moreover, for carbon nanotube materials, this method does not provide complete information about their electrical properties. The electrical properties of carbon nanotube materials can be better described by their electrical conductivity.

The primary objective is to extend the NIST measurement procedure to make non-contact measurements of the scattering S parameters from reflected and transmitted microwaves of carbon nanotube materials. These measurements would provide the necessary information to calculate the complex impedance and, consequently, allow

for the determination of the conductivity of these materials. Such a non-contact method of characterization of the complex impedance and conductivity of carbon nanotube materials would provide an opportunity for the rapid and accurate assessment of their electrical properties that can be used in quality control and assessment of their manufacture process.

Phase 1 Activities and Deliverables:

1. Measurement design for complex conductivity that incorporates results from modeling of electromagnetic wave propagation in carbon nanotube composite materials (see below):

a. Nanocomposite material that consists of a percolated network of carbon nanotubes uniformly dispersed in a non-conducting dielectric. The total thickness of nanocomposite will be in the range of 200 μm to 500 μm .

b. Nanocomposite material that consists of a dielectric core layer coated with carbon nanotubes on one or on both sides. The thickness of the dielectric core will be in the range of 200 μm to 500 μm , while the thickness of the carbon nanotube coating will be about 10 μm .

2. Establish and demonstrate the feasibility of the measurements for a sensitive determination of the complex conductivity of the carbon nanotube composite materials described above in the frequency range of 50 MHz to 12 GHz.

Phase 2 Activities and Deliverables:

1. Demonstrate and deliver a working prototype for sensitive, non-contact determination of the complex conductivity at frequencies of up to 12 GHz.

2. Demonstrate the sensitivity and reproducibility of the measurements.

3. Utilize the new design to characterize the electrical properties of monolayer semiconducting and dielectric fabrics.

4. Utilize the new design to determine the complex conductivity of multi-layer materials, consisting of one or two semiconducting layers separated by a dielectric layer. The frequency range will be between 50 MHz and 12 GHz.

During Phase 1, NIST staff will be available to address questions about the previous measurement development of complex conductivity and help evaluate the proposed new non-contact measurement procedure of electrical properties for nanofiber materials from reflected and transmitted microwaves. Test samples of the relevant

nanofiber materials will be made available. During Phase 2, NIST staff will test a measurement prototype for the determination of the nanofabric complex conductivity at frequencies of up to 12 GHz.

References:

1. J. Obrzut, N. Noda and R. Nozaki, "Broadband Characterization of High-Dielectric Constant Films for Power-Ground Decoupling", IEEE Trans. Instr. Meas., vol. 51, pp.829 – 832 (2002).
2. J. Obrzut and A. Anopchenko, "Input Impedance of a Coaxial Line Terminated With a Complex Gap Capacitance - Numerical and Experimental Analysis", IEEE Trans. Instr. Meas., vol. 53, pp. 1197- 1201 (2004).
3. J. Obrzut in *Springer "Handbook of Metrology and Testing"*, H. Czichos, T. Saito, L. Smith (Eds.), Ch.9, pp. 532 (2011).
4. J. Obrzut, B. Schumacher, H.G. Bach, P. Spitzer, "*Springer Handbook of Metrology and Testing, Ch.9 Electrical Properties*" Springer Handbook of Metrology and Testing, Chapter: Electrical Properties, Springer, Springer Science and Media Inc., Heidelberg, -1, 69047, Germany, pp. 485-540, (01-Aug-2011).

9.02.05.68-R Power Meter for EUV Lithography Sources

Extreme-ultraviolet lithography (EUVL) will be the next-generation technology used in the manufacturing of integrated circuits with small critical dimension. EUVL production tools require extremely high-power sources of EUV radiation to print wafers at a commercially viable rate. The semiconductor industry faces the daunting task of determining the output of these EUV sources, which will operate at average power levels of approximately 200 W initially. Over time, the source power may increase to as much as 500 W. As EUVL is integrated into fabrication facilities, a commercial market will exist for devices to measure EUVL source power with NIST traceable calibration. NIST as well as the semiconductor industry and its suppliers must be prepared to provide calibration services for the measurement of EUVL source power. Currently there is no technology that can reliably measure such high EUV power. NIST seeks a measurement instrument and method that can be calibrated at NIST and which is capable of determining the output power from a 500 W (200 ns pulsed radiation at a frequency between 1 kHz and 100 kHz) source for EUVL with an standard uncertainty of 5 % or less over a period of 12 months of use. NIST will use the developed instrument and method to transfer the EUV detector responsivity scale from the NIST laboratory to industry facilities, and industry will use them to monitor the performance of sources on fabrication lines.

The instrument and method described in the previous section shall meet the following specifications:

Nominal Wavelength: 13.4 nm

Bandpass: 1 % of nominal wavelength

Maximum Incident Power: 500 W at the output of the EUVL source, i.e. at the intermediate focus of an EUVL tool. The power need not be measured at the intermediate focus, provided that the power at the intermediate focus can be derived from the measurement result with the specified uncertainty.

Out-of-Band Rejection: 104 outside of the 5 % bandpass centered at the nominal wavelength.

Measurement Uncertainty: The instrument and method shall determine the in-band power from an EUVL source with output power between 200 W and 500 W with a standard uncertainty of 2 % or less immediately after calibration by NIST. Assume that NIST can calibrate the instrument and method with 1 % uncertainty when 100 nW is incident in a 4 mm by 4 mm square aperture provided that the signal-to-noise ratio of the instrument and method is sufficiently high.

Temporal Stability: The responsivity shall not change more than 3 % over 12 months while stored in a typical laboratory atmosphere.

Radiation Hardness: The responsivity shall not change by more than 3 % when exposed to an accumulated dose equivalent to use for 1 minute on a 500 W EUVL source every week for 52 weeks.

NIST Calibration Conditions: EUV detector calibrations at NIST are normally performed at a synchrotron radiation facility using monochromatic radiation with a resolving power greater than 150. The available power is of order 100 nW in an approximately 4 mm by 4 mm collimated beam. The radiation is linearly polarized to a high degree. The NIST responsivity scale has a standard uncertainty of approximately 0.5 % at 13.4 nm wavelength. Additional uncertainty, including signal-to-noise ratio, resulting from the transfer of this scale to the developed instrument must not increase the total uncertainty to greater than 1 %.

Phase 1 Activities and Deliverables:

- Detailed optical design of instrument and method
- Detailed mechanical design of instrument and method
- Experimental characterization of representative sample for all components to be used (e.g., reflectivity of mirrors, responsivity and linearity of photodiodes)

- Analysis of expected performance, especially linearity and radiation hardness at full source power

Phase 2 Activities and Deliverables:

- Fully functional prototype instrument and method suitable for determination of the output power of a 500 W EUVL lithography source

NIST is ready and willing to support the awardee through discussions and consultation and by performing a limited number of measurements of reflectivity, transmission, diffraction efficiency, or responsivity on individual optical components, subassemblies, or assembled instruments. Measurements are contingent on the availability of sufficient time and staff resources.

9.02.06.73-R Query-based Geometric Interoperability for Advanced Manufacturing

Advanced manufacturing requires adaptable, trustable, and affordable solutions in model-based engineering (MBE) and platform-based engineering (PBE). Limited or poor geometric interoperability of the software supporting manufacturing and other engineering activities within the product lifecycle is becoming a barrier not only for MBE but also curtails the potential benefits of PBE. Using a query-based approach that is informed by the highly successful systems strategy for service-oriented architecture (SOA), these barriers can be overcome, suggesting the concepts of model interchangeability, interoperability, and integration. We solicit standardizable query-based methodologies and tools that can be commercialized for several geometric interoperability tasks commonly arising in manufacturing.

The project has three major goals: (1) A rigorous study of the feasibility of query-based approach to geometric interoperability for a class of advanced manufacturing applications; (2) A software demonstration of such an approach on a realistic scenario in advanced manufacturing; and (3) Demonstration of a commercial-quality software to solve an actual industrial problem in advanced manufacturing in collaboration with a U.S. manufacturer.

Phase 1 Activities and Deliverables:

- (1) A rigorous study proving that a query-based approach is feasible for geometric interoperability for advanced manufacturing. The deliverable is a high-quality report.
- (2) Development of algorithms and early software pieces to demonstrate the query-based approach. The deliverables are reports of high-level algorithms and a software demonstration.

Phase 2 Activities and Deliverables:

- (1) Development of advanced manufacturing use-cases, and development of application software for query-based geometric interoperability in these use-cases. The deliverables are recommendations of standardized queries and software demonstrations of query-based geometric interoperability in these use-case scenarios.
- (2) Development of commercial-quality software that implements query-based geometric interoperability. The deliverable is a software demonstration of solving an actual geometric interoperability problem faced by a U.S. manufacturer using the (proposed) standardized query-based approach.

Work collaboratively during all phases of the project, as it is important to the mission of NIST in the area of advanced manufacturing.

References:

- (1) SOA Approach to Enterprise Integration for Product Lifecycle Management, IBM Redbook, International Technical Support Organization, Oct. 2008.
- (2) V. Srinivasan, L. Lammer, and S. Vettermann, "On Architecting and Implementing a Product Information Sharing Service," ASME Journal of Computing and Information Science in Engineering, Vol. 8, March 2008.
- (3) V. Srinivasan, "Standardizing the Specification, Verification, and Exchange of Product Geometry: Research, Status and Trends," Computer-Aided Design, Vol. 40, pp. 738-749, 2008.

9.02.07.68-R Silicon Ion Source for Isotopically Enriched Deposition

This project concerns a method of manufacture of isotopically enriched silicon for development of future-generation electronics. Spin-based electronics ("spintronics") and quantum information in solid-state systems both require materials with very long quantum (or spin) decoherence times. Silicon is a natural material choice due to the massive infrastructure in equipment and established processing techniques. It also has a naturally high abundance of silicon-28 (~93 %), which has a zero nuclear spin. Pure spin-0 material would minimally decohere the spin states of the electron currents.

NIST is developing the capability to produce isotopically enriched silicon by extracting silicon ions from an ion source, isolating a single isotope using a sector mass analyzer, and depositing the ions epitaxially onto a silicon substrate of natural isotopic abundance. In order to realize the benefit of the isotopic enrichment, industry standards for chemical purity and crystalline perfection must be maintained, e.g., $< 10^{16}/\text{cm}^3$. These demands require deposition fluxes as high as possible to reduce likelihood of environmental contamination during growth. Therefore, a high-flux source of singly charged silicon ions suitable for mass purification and solid state deposition is required.

The ultimate objective is to develop a silicon ion source that can produce high enough fluences to allow solid state deposition at greater than two monolayers (ML) per second, with obvious scale-up pathways to 20 ML/s over areas of technological relevance (e.g., a 100 mm diameter wafer). This source should produce singly charged ions predominantly. Further, since chemical purity is a critical consideration, an ion source constructed using ultra-high vacuum compatible techniques (to minimize environmental leakage) is required, even though operating conditions will likely require high-purity source gasses at higher pressures.

Since many ion sources are currently available in the marketplace, NIST would expect that identification of an ion source design and production of a low-flux prototype could be performed rapidly (Phase 1), with developmental in Phase 2 devoted to proving scale-up of the ion current and identification of most efficient mass purification strategies specific to the source. Production of a prototype (and low-flux) silicon ion source in Phase 1 is expected to be relatively low risk and may be based on existing technology. However, rational for expecting success in scale-up to larger deposition areas and growth rates must be provided.

The Phase 1 prototype should be capable of producing growth rates of >2 ML/s second, but over smaller areas (>10 mm²)—corresponding to approximately 100 μ A of total current. An awardee must be willing to work collaboratively with NIST to ensure compatibility between the developmental ion source and NIST's developmental sector mass analysis system to provide for adequate testing and demonstration of feasibility. Special considerations for hazardous materials handling or exhaust/waste abatement must be clearly identified and described. While optimization of the operating conditions may bridge into a Phase 2 project to determine maximal fluences for this prototype, operating conditions that can meet the requirements for >2 ML/s over 10 mm² should be identified. Operation of the source should be possible for times that are at least ten times the time required to perform any routine service interval, e.g., replacement of cathodes, grids, cleanouts, etc.

Phase 2 of the project would be devoted the scale-up in growth rate and area of growth. Since many markets for wafer scale silicon deposition can be identified beyond mass purified epitaxial layers, the objective is to produce an ion source that support wafer scale (100 mm diameter) deposition at reasonable growth rates of >2 ML/s with a target uniformity of 10 % variation over the size of the wafer. Attaining growth rates of 20 ML/s over areas of at least 10 cm² should also be possible if 20 ML/s grow rates over the entire wafer is deemed infeasible within the scope of this project. Since the motivation for the project is to produce isotopically enriched silicon epi-layers, a method for mass purifying the emitted ions without a substantial (factor of 2) degradation in the growth rate(s), area(s) and uniformity should be identified (if demonstration is not feasible within the scope of this project) and supported by analytical calculations, modeling, or reduced scale experimental measurements.

Phase 1 Activities and Deliverables

- Identification of method for producing silicon ions at 100 μA scale with possibility for scale-up to wafer scale.
- Delivery of a 100 μA scale prototype silicon ion source for coupling with sector mass analyzer and NIST isotopic enrichment tests. NIST will retain the prototype.
- Clear and complete descriptions of any hazardous materials storage, delivery, exhaust, or abatement procedures required in support of the source operations.
- Identification of operating parameters for producing 100 μA silicon ions.
- Analytical calculations or modeling supporting technical plans for scale-up to full size ion source.

Phase 2 Activities and Deliverables

- Support in the form of analytical calculations, modeling, or technical expertise for operating the prototype ion source with the sector mass analyzer.
- Optimized parameters for operation of the prototype ion source.
- Updates regarding operation of Phase 1 prototype due to experience gained from full-scale ion source testing.
- Experimental demonstration (ion current measurements, uniformity measurements, etc.) of ion source and technical description of optimized operating conditions.
- Analytical calculations or modeling supporting technical plans for mass purification or for coupling of ion source to NIST sector mass analyzer.
- Delivery of full scale ion source prototype for NIST testing and evaluation. NIST will retain the prototype.
- Statement of feasibility for extending source operation to materials other than silicon, e.g., germanium.

Since the Phase 1 prototype must be compatible with the NIST mass purifier, collaboration is anticipated. Phase 2 would be expected to involve mutual exchange of information as NIST operates the prototype and the awardee develops a full-scale version to benefit both parties. Ultimately the awardee would be working increasingly independent as the full-scale ion source was optimized.

9.02.08.68-TT X-ray Chemical Shift Mapping for Industrial Materials Analysis

** This subtopic requires that a license [application](#) be submitted in conjunction with the proposal. Be sure to include one, signed copy along with the proposal package.*

X-ray fluorescence spectroscopy is a widely used technique with electron microscopy to detect elemental composition in micro- and nanostructures. This capability is particularly useful for defect and failure analysis in the semiconductor industry. However, x-ray fluorescence spectroscopy can presently only be used to obtain elemental information; chemical information is inaccessible.

Recent technological developments at NIST now raise the possibility of extending the utility of x-ray fluorescence spectroscopy from the elemental regime into the chemical regime. In particular, the performance of energy-resolving superconducting sensors pioneered by NIST [1] is now good enough to resolve small shifts in x-ray line positions and line shapes that reveal the bonding state of the fluoresced atoms [2,3]. The successful commercialization of these sensors will allow the rapid generation of chemical-shift maps that will be powerful diagnostic tools during semiconductor circuit manufacturing.

Chemical shift mapping will produce an enormous qualitative improvement in the information returned by energy-dispersive x-ray fluorescence spectroscopy. It will be possible to distinguish elemental materials from their oxides, nitrides, and silicides. It will be possible to detect unwanted interface chemistry caused by material incompatibilities or environmental degradation. The chemical shift maps that this SBIR will enable will be a new and powerful tool for the diagnosis of faults in semiconductor circuits.

The x-ray diagnostic capability described here is novel and not presently available to industry. Some chemical information can be obtained from alternative electron spectroscopies, but these techniques require ultrahigh vacuum and are not compatible with industrial requirements for rapid sample exchange and measurement. In contrast, x-ray techniques require only high vacuum and can be implemented on conventional electron microscopes already used by industry for imaging.

In this project, we seek the development and demonstration of arrays of Transition-Edge Sensor (TES) microcalorimeters optimized for x-ray chemical shift detection. Further, we seek the demonstration of supporting cryogenics and pulse processing techniques to allow the real-time generation of chemical shift spatial maps by a TES array mounted on an electron microscope.

Phase 1 Activities and Deliverables:

- Demonstrate x-ray chemical shift detection using a single TES sensor with energy resolution better than 2 eV Full-Width-at-Half-Maximum (FWHM) for 1.5 keV x-rays.
- Demonstrate sensor performance that includes > 90 % efficiency at 1.5 keV, an area greater than 104 μm^2 , and a response time < 1 ms.

Phase 2 Activities and Deliverables:

- Demonstrate a homogeneous array of 8-16 TES sensors for increased collection area mounted on an electron microscope.
- Demonstrate real-time pulse processing techniques that provide energy resolution better than 2 eV FWHM at 1.5 keV. The pulse processor should be synchronized with the electron microscope to allow the generation of x-ray maps with elemental and chemical shift information. The pulse processor should also energy calibrate the individual elements of the array.
- Measure and provide NIST with chemical shift maps of five NIST-selected, industrially relevant samples.

NIST will provide technical assistance to the successful applicant. In addition to consultation and discussions, this assistance will include limited sensor testing and guidance on high-resolution sensor designs, real-time pulse processing algorithms, and the construction of array packages with uniform magnetic and thermal properties. NIST has extensive experience in these areas from prior internal projects.

References:

[1] See, e.g., <http://www.nist.gov/pml/div686/devices/sensors.cfm>.

[2] G. C. Hilton, D. A. Wollman, K. D. Irwin, L. L. Dulcie, N. F. Bergren, and J. M. Martinis, "Superconducting Transition Edge Microcalorimeters for X-ray Microanalysis," *IEEE Transactions on Applied Superconductivity* 9 (2) pp. 3177–3181 (1999).

[3] D. A. Wollman, G. C. Hilton, K. D. Irwin, et al., "High-resolution microcalorimeter energy-dispersive spectrometer for x-ray microanalysis and particle analysis," *Characterization and Metrology for ULSI Technology*, AIP Conference Proceedings 449 pp. 799–804 (1998).

* U.S. Patent 6,239,431, "Superconducting Transition-edge Sensor with Weak Links", G. Hilton, K. Irwin, J. Martinis, and D. Wollman, May 29, 2001.

